N00213.AR.001179
NAS KEY WEST
5090.3a

REMEDIAL ACTION PLAN ADDENDUM FOR ELECTRIC POWER PLANT BUILDING 103 NAS KEY WEST FL

3/1/1995

ABB ENVIRONMENTAL SERVICES INC

REMEDIAL ACTION PLAN ADDENDUM

ELECTRIC POWER PLANT, BUILDING 103
NAVAL AIR STATION KEY WEST
KEY WEST, FLORIDA

Unit Identification Code (UIC): N00213

Contract No. N62467-89-D-0317/007

Prepared by:

ABB Environmental Services, Inc.
2590 Executive Center Circle, East
Tallahassee, Florida 32301

Michael K. Dunaway, P.E., P.G.
F. Joseph Ullo, Jr., E.I.T.

Prepared for:

Department of the Navy, Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, South Carolina 29418

Gabriel Magwood, Code 1849, Engineer-in-Charge

March 1995

CERTIFICATION OF TECHNICAL
DATA CONFORMITY (MAY 1987)

The Contractor, ABB Environmental Services, Inc., hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0317/007 are complete and accurate and comply with all requirements of this contract.

DATE: March 8, 1995

NAME AND TITLE OF CERTIFYING OFFICIAL: Mark C. Diblin, P.G.
Task Order Manager

NAME AND TITLE OF CERTIFYING OFFICIAL: Michael K. Dunaway, P.E., P.G.
Project Technical Lead

(DFAR 252.227-7036)

FOREWORD

Subtitle I of the Hazardous and Solid Waste Amendments (HSWA) of 1984 to the Solid Waste Disposal Act (SWDA) of 1965 established a national regulatory program for managing underground storage tanks (USTs) containing hazardous materials, especially petroleum products. Hazardous wastes stored in USTs were already regulated under the Resource Conservation and Recovery Act (RCRA) of 1976. Subtitle I requires that the U.S. Environmental Protection Agency (USEPA) promulgate UST regulations. The program was designed to be administered by individual States, who were allowed to develop more stringent, but not less stringent standards. Local governments were permitted to establish regulatory programs and standards that are more stringent, but not less stringent than either State or Federal regulations. The USEPA UST regulations are found in the Code of Federal Regulations, Title 40, Part 280 (40 CFR 280) (*Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks*) and 40 CFR 281 (*Approval of State Underground Storage Tank Programs*). 40 CFR 280 was revised and published on September 23, 1988, and became effective December 22, 1988.

The Navy's UST program policy is to comply with all Federal, State, and local regulations pertaining to USTs. This report was prepared to satisfy the requirements of Chapter 62-770, Florida Administrative Code (FAC) (*State Underground Petroleum Environmental Response*) regulations on petroleum contamination in Florida's environment as a result of spills or leaking tanks or piping.

Questions regarding this report should be addressed to the Commanding Officer, Naval Air Station, Key West, Florida, or to Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), Code 1842, at 803-743-0307 (AUTOVON 563-0307).

EXECUTIVE SUMMARY

The purpose of this Remedial Action Plan (RAP) Addendum is to address comments made by the Florida Department of Environmental Protection (FDEP) regarding the RAP prepared for Truman Annex (Site 103) at Naval Air Station Key West, Key West, Florida, in August 1994.

The original RAP set forth a procedure of excavation and destruction of contaminated soil at Site 103. The area to be excavated is also associated with the existing free product. Free product recovery is proposed through direct excavation and product pumping if necessary. Evidence exists showing groundwater containment and natural attenuation of contaminants.

This RAP Addendum includes responses to FDEP comments dated January 26, 1995. Major comments posed by FDEP focus on the following issues:

- permeability of the bulkhead wall and
- method of treatment for contaminated groundwater and lighter-than-water nonaqueous phase liquid (LNAPL).

Supporting documentation for these responses and copies of previous correspondence are included as appendices.

ACKNOWLEDGMENTS

In preparing this report, the Underground Storage Tank personnel at ABB Environmental Services, Inc., acknowledges the support, assistance, and cooperation provided by the personnel at Naval Air Station (NAS) Key West and Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM).

TABLE OF CONTENTS

Remedial Action Plan Addendum
Electric Power Plant, Building 103
Naval Air Station Key West
Key West, Florida

GLOSSARY

ABB-ES	ABB Environmental Services, Inc.
ASTM	American Society for Testing and Materials
BEI	Bechtel Environmental, Inc.
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action, Navy
cm/s	centimeters per second
CTO	Contract Task Order
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
GAC	granular activated carbon
HSWA	Hazardous and Solid Waste Amendments of 1984
LNAPL	lighter-than-water nonaqueous phase liquid
msl	mean sea level
NAS	Naval Air Station
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
SOUTHNAV-FACENGCOM	Southern Division, Naval Facilities Engineering Command
SWDA	Solid Waste Disposal Act of 1965
UIC	unit identification code
USEPA	U.S. Environmental Protection Agency

1.0 INTRODUCTION

A Remedial Action Plan (RAP) for Building 103 at Naval Air Station (NAS) Key West, Florida, was submitted by ABB Environmental Services, Inc. (ABB-ES), in August 1994 to Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM). Comments from Florida Department of Environmental Protection (FDEP) were returned to ABB-ES in November 1994. These comments were addressed by ABB-ES and the responses were reviewed by FDEP in January 1995. FDEP requested that additional information and documentation be submitted in the form of an RAP Addendum. In this RAP Addendum, the latest FDEP comments (Appendix A) are addressed, and supporting documentation is included in Appendices B and C. The initial FDEP comments and the associated responses are included in Appendix D. This work is being performed under Contract Task Order (CTO) No. 007 of the Comprehensive Long-term Environmental Action, Navy (CLEAN) contract.

This RAP Addendum should be combined with the original RAP for FDEP review. A site characterization and details of the original contamination assessment can be found in the Contamination Assessment Report (ABB-ES, 1992b) and the Contamination Assessment Report Addendum (ABB-ES, 1993).

2.0 RESPONSE TO FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION (FDEP) COMMENTS, JANUARY 26, 1995

The latest comments by Greg Brown (FDEP) dated January 26, 1995, have been reviewed by ABB-ES. To comply with FDEP's direction for a No Further Action finding, responses to these comments are detailed below.

Comments regarding responses 4 and 7 will be addressed simultaneously as each has a primary focus on the permeability of the bulkhead wall. ABB-ES has obtained sealed record drawings showing characteristics of the bulkhead wall that support the claim that the wall is impermeable and should not be considered a pathway for contaminant transport. These drawings are included in Appendix B. Specific notes and details that support claims made by ABB-ES are itemized below.

> The bulkhead is encapsulated within the top 10 feet with concrete measuring at least 8 inches in thickness on the outer face. The base of the encapsulation is 3 feet below mean sea level (msl) as shown in Detail E-4. Rubber water stops have also been included in the concrete joints as shown in Detail E-2. Together, these precautions will effectively prevent any shallow groundwater contaminant transport through the bulkhead.
>
> Below the encapsulation, PZ hot rolled steel sheet piling as shown in Details E-2 and E-5 extends to 53 feet below msl into the turning basin floor. Sheet piling of this type with conventional unsealed joints has been tested and values of hydraulic conductivity on the order of magnitude of 10^{-7} centimeters per second (cm/s) have been recorded. A description of the test and its results are included in Appendix C.
>
> In Detail E-4, note 2, the original detail called for all carbon steel plates, bolts, nuts, washers, waling, steel sheet piling, and steel H-piling to receive a coal-tar coating prior to installation. This was later amended as shown, and coal-tar was changed to an epoxy coating. This coating should prevent corrosion of the wall and will also act as a water sealant.
>
> Backfill as shown in Diagram E-5 was compacted to 95 percent of American Society for Testing and Materials (ASTM) D1557 maximum density. This compaction will lower the conductivity of the given material and should sufficiently prevent contaminant transport.
>
> Detail E-8 diagrams the resilient foam filled marine fenders that were put in place of the former timber fender system. This is designed to prevent significant damage to the bulkhead under most circumstances (i.e., minor collisions with ships or barges).

The second comment was concerned with infiltrating water and lighter-than-water nonaqueous phase liquid (LNAPL). The groundwater and free product recovery method will be chosen by the Remedial Action Contract contractor (Bechtel Environmental, Inc., [BEI]), and to allow for some flexibility in this selection, only general requirements are specified.

The following options are recommended, however, other options may be used with prior approval from the FDEP:

Product sorbing materials will be used to recover any product that filtrates into the excavation. This material will be removed when saturated and drummed onsite. These containers will be removed from the site by a licensed petroleum recycling agent or as a hazardous waste depending on waste characterization.

A tanker truck with vacuum connections will be used to capture free product. A licensed petroleum recycling agent will remove the free product and any incidentally captured groundwater and provide for offsite disposal. Contaminated groundwater captured during product recovery may be treated onsite by granular activated carbon (GAC) and discharged to the sanitary sewer. Spent GAC will be regenerated by a qualified carbon vendor. BEI will include copies of manifests and receipts showing proper disposal as appropriate in follow up reports submitted to the Base Environmental Coordinator at NAS Key West and to SOUTHNAVFACENGCOM.

3.0 PROFESSIONAL REVIEW CERTIFICATION

This RAP Addendum was prepared using standard engineering practices and designs. The plan for remediating this site is based on the information collected between August 1991 and August 1993 and engineering detailed in the text and appended to this report. If conditions are determined to exist differently than those described, the undersigned professional engineer should be notified to evaluate the effects of any additional information on the design described in this report.

This RAP Addendum was developed for Site 103, Truman Annex, NAS Key West, Florida, and should not be construed to apply to any other site.

Michael K. Dunaway 3/8/95
P.E. No. 39451
Principal Engineer

REFERENCES

ABB Environmental Services, Inc. (ABB-ES), 1992a, Comprehensive Quality Assurance Plan: Tallahassee, Florida.

ABB-ES, 1992b, Contamination Assessment Report, Electric Power Plant, Building 103, Truman Annex, NAS Key West, Florida: prepared for Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), Charleston, South Carolina, September.

ABB-ES, 1993, Contamination Assessment Report Addendum, Electric Power Plant, Building 103, Truman Annex, NAS Key West, Florida: prepared for SOUTHNAVFACENGCOM, Charleston, South Carolina, September.

ABB-ES, 1994, Remedial Action Plan, Electric Power Plant, Building 103, Truman Annex, NAS Key West, Florida: prepared for SOUTHNAVFACENGCOM, Charleston, South Carolina, August.

Florida Department of Environmental Protection (FDEP), 1994, Guidelines for Assessment and Remediation of Petroleum Contaminated Soil: Division of Waste Management, May.

Starr, R.C., and Cherry, J.A., 1992, Applications of low permeability cutoff walls for groundwater pollution control: 45th Canadian Geotechnical Conference, October 26-28, Toronto, Ontario.

Starr, R.C., Cherry, J.A., and Vales, E.S., 1992, A new type of steel sheet piling with sealed joints for groundwater pollution control: 45th Canadian Geotechnical Conference, October 26-28, Toronto, Ontario.

APPENDIX A

FDEP COMMENTS DATED JANUARY 26, 1995

Florida Department of

Environmental Protection

Memorandum

TO: Jorge Caspary, P.G., Remedial Project Manager, Technical Review Section

THROUGH: Tim Bahr, P.G., Supervisor, Technical Review Section TB

FROM: Greg Brown, P.E. II, Technical Review Section AB

DATE: October 26, 1994

SUBJECT: Remedial Action Plan for Site 103 at Truman Annex for Naval Air Station, Key West, Florida, August 1994.

I have reviewed the subject document and my specific comments are attached. I recommend that the Navy proceed with the limited soil and free product removal described in the RAP as an interim remedial action. Other important issues remain outstanding, however. The Navy must adequately address them before the RAP can be approved. These include:

- provide sufficient justification that all pathways to potential receptors under likely exposure scenarios have been eliminated;
- provide adequate evidence that the bulkhead is impermeable; and
- prepare and implement a monitoring plan.

The limited remedial action proposed in the RAP may be justified if a better effort is made in the document to show that weak exposure pathways exist under likely exposure scenarios. The impermeability of the bulkhead is also a critical issue since there may be a direct link between contaminated ground water and receiving surface water bodies. Because contaminated ground water and excessively contaminated soil will be left on-site, monitoring will be required until no further action criteria are achieved in affected media. If you have questions, please call me.

Engineering Review Comments; Remedial Action Plan for Site 103 at Truman Annex, NAS Key West; Gregory M. Brown, P.E.; October 26, 1994.

No.	*Page/Para*	*Comment*	*Response Required?*
1	General	Appendix B contains correspondence that documented decisions and data gaps to be addressed in the RAP. Specifically: 1) The RAP must present supporting data that all pathways for potential receptors of contamination have been eliminated; (2) The RAP must provide backup documentation to support the theory that the dock bulkhead is impermeable; and (3) The RAP should contain recommendations for soil and product removal in the vicinity of monitoring well MW-14. The RAP accomplishes item three satisfactorily, but none of the others. In addition, the specific requests made in the July 25, 1994 letter from J. Caspary (FDEP) to G. Magwood (SDIV) were not adequately addressed in the RAP. I recommend that the Navy include any risk evaluation summary presented in the CAR to support the lack of exposure pathways. The RAP could use the conclusions and recommendations of the risk evaluation as the basis of their remediation strategy. This would resolve some of the subsequent comments.	Yes
2	page 3-1/ para iii	"Exposure pathways through the soil media are limited; the latter two areas are not considered to contain contaminants of concern." The meaning of this statement is unclear. What exposure pathways? Are there no contaminants of concern because there are no exposure pathways or are there no exposure pathways because there are no contaminants of concern? Since by definition, the three areas shown in Figure 3-2 contain excessively contaminated soils as defined in FAC 62-770, the former condition must apply. Please request the Navy to make more explicit their rationale for this statement including their assumed exposure scenarios. (Answer to comment 1 may help resolve my confusion on this issue.)	Yes
3	Figures 3-3	I am not sure what figure 3-3 is trying to convey. The legend indicates that the shaded area to the west is ≤50 ppm. Is this a typo or does it mean that the unshaded areas are greater than 50 ppm (i.e. ≥50 ppm)?	Yes
4	page 3-6/para ii and iii	Tidal induced ground water fluctuations reduces the credibility of the "theory" that the bulkhead is hydraulically impermeable and is an effective barrier to contaminant migration. The Navy should report the magnitude and upland extent of the tidal influence and assess the extent of the hydraulic connection between ground water and surface water in a more quantitative manner. If enough data exist, a flow net analysis may be one of various methods adequate to accomplish it. Any persuasively presented analysis based on good scientific principles will be acceptable. Page 2-1, Section 2.2 reports that "There are existing underground utilities throughout the pier area..." Damaged and inadequately maintained storm drains through similar bulkheads at other Naval bases (e.g., NS Mayport, Alpha Delta pier) have acted as direct conduits to surface water for contaminated ground water. The Navy should adequately verify that they have considered and eliminated this potential release mechanism at Site 103, as well.	Yes
5	Table 4-1	Include Total Organic Halides	No
6	pg 4-1 / v	How are recovered water and LNAPL to be managed?	Yes
7	page 4-4	Excessively contaminated soil and contaminated ground water will remain after the removal of the LNAPL and associated soils. What is the monitoring plan?	Yes

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

January 26, 1995

Mr. Gabriel Magwood
Southern Division
Naval Facilities Engineering Command
2155 Eagle Dr., P. O. Box 10068
Charleston, South Carolina 29411-0068

RE: Remedial Action Plan Responses, Electric Power Plant, Building 103, Naval Air Station Key West, Florida

Dear Mr. Magwood:

Department personnel have reviewed the above referenced responses dated January 6, 1995 (received January 9, 1995). Attached you will find our comments. The reponses to our observations should be addressed as part of a RAP Addendum.

If I can be of any assistance in this matter, please contact me at 904/488-3935.

Sincerely,

Jorge R. Caspary

Jorge R. Caspary, P.G.
Remedial Project Manager

cc: Bill Carlye, NAS Key West
Mark Diblin, ABB-Tallahassee

TJB TB JJC JJC ESN ESN

Florida Department of

Environmental Protection

Memorandum

TO: Jorge Caspary, P.G., Remedial Project Manager, Technical Review Section

THROUGH: Tim Bahr, P.G., Supervisor, Technical Review Section TB

FROM: Greg Brown, Professional Engineer II, Technical Review Section GB

DATE: January 20, 1995

SUBJECT: Navy Response (January 6, 1995) to Department Comments (October 26, 1994); Remedial Action Plan, Electric Power Plant, Building 103, Naval Air Station, Key West

I have reviewed the Navy's responses dated January 6, 1995 (recieved January 9, 1995) to the Department's comments on the subject document and I have the following observations.

Responses to comments 1, 2, and 3 are acceptable.

Response to comment 4 is acceptable with the following qualifications. Questions remain as to the bulkhead's impermeability. Item 2 of the Department's letter dated July 25, 1994, has not been adequately addressed. Item 2c of the subsequent memorandum dated August 4, 1994, provided by the Navy's consultant, has not been adequately addressed. Without credible evidence showing that the bulkhead is impermeable, groundwater transport still exists as a potential migration pathway to surface water.

The Navy's response did provide an analysis of contamination fate and transport using a simple model, site-specific data, and literature values. Their simple analysis indicates present groundwater contamination migration to surface water is likely to be minimal and thus does not presently pose a threat to human health or the environment. This simple analysis supports the judgment that active remediation of groundwater is not necessary at this time. The Department is also thankful for the additional information provided by the Navy on the storm drains.

Response to Comment 6 is inadequate. How will the recovered water and LNAPL be treated, properly disposed of, and by whom? If specifics are not known, then the Navy should state the general standards that will be followed. For example, one may pose "Contaminated groundwater will be treated on-site by granular activated carbon and discharged to the sanitary sewer. Spent GAC will be regenerated by a qualified carbon vendor.

LNAPL will be managed by a licensed petroleum recycling agent or as a hazardous waste depending on its characterization. The quantities and disposition of treated groundwater and LNAPL will be recorded by Navy personnel responsible for waste management or by their authorized representatives."

Response to Comment 7 is inadequate. The Navy has not provided credible evidence showing that the bulkhead is impermeable. Credible evidence would be a competent assessment of the site specific construction of the bulkhead and its impact on site hydrology. As an alternative, they have provided an analysis using a simple fate and transport model indicating that groundwater contamination migrating to surface water is minimal. The Department cannot make a No Further Action finding when fate and transport models are used for predictive analysis. The Navy will need to monitor the site. Once again, if the Navy can provide credible evidence that the bulkhead is impermeable and will remain so, a No Further Action finding may be feasible (e.g., comply with the direction given in Item 2 of the Department's letter dated July 25, 1994, and Item 2c of the subsequent memorandum dated August 4, 1994, provided by the Navy's consultant).

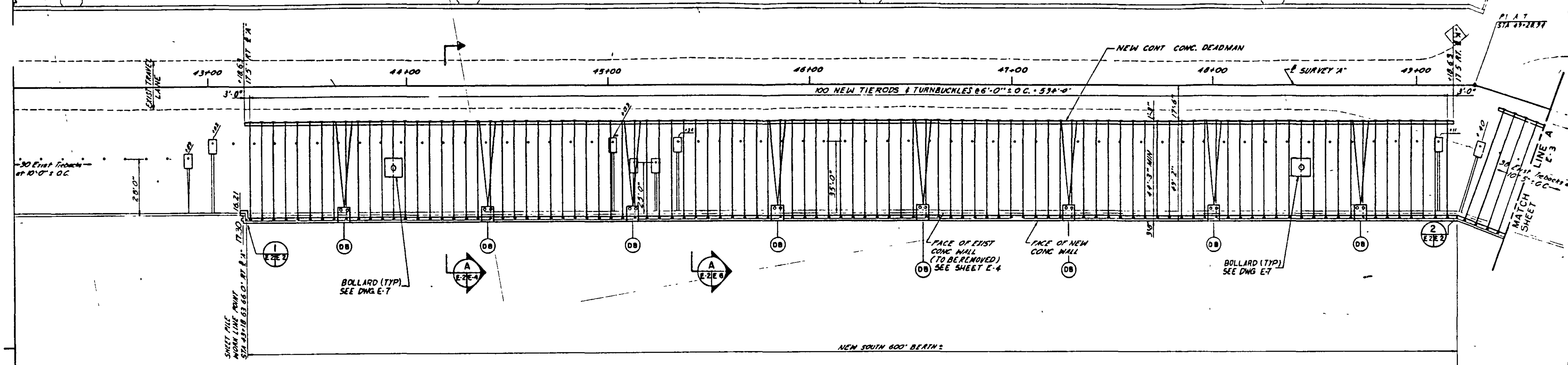
The Navy has two choices to achieve RAP approval. They can revise the RAP to include the clarifying information provided in their approved responses, and they can provide credible evidence showing that the bulkhead is impermeable and will remain so for the foreseeable future. A No Further Action finding could then be justified after the contaminated soil and free-product are adequately removed.

The second choice is to revise the RAP to include the clarifying information provided in their approved responses, the fate and transport model, and a monitoring program in accordance with Department rules and guidance. A Monitoring Only finding could then be made after the contaminated soil and free-product are adequately removed. The Navy is still encouraged to implement the soil and free-product removal as soon as possible as an IRA. They do not need RAP approval to implement these removal actions.

Please remind the Navy that their design engineers should be sure to sign and seal their RAPs before submitting them to the Department.

APPENDIX B

RECORD DRAWINGS
BERTHING IMPROVEMENTS, TRUMAN ANNEX,
NEW WALL SECTIONS, AND DETAILS

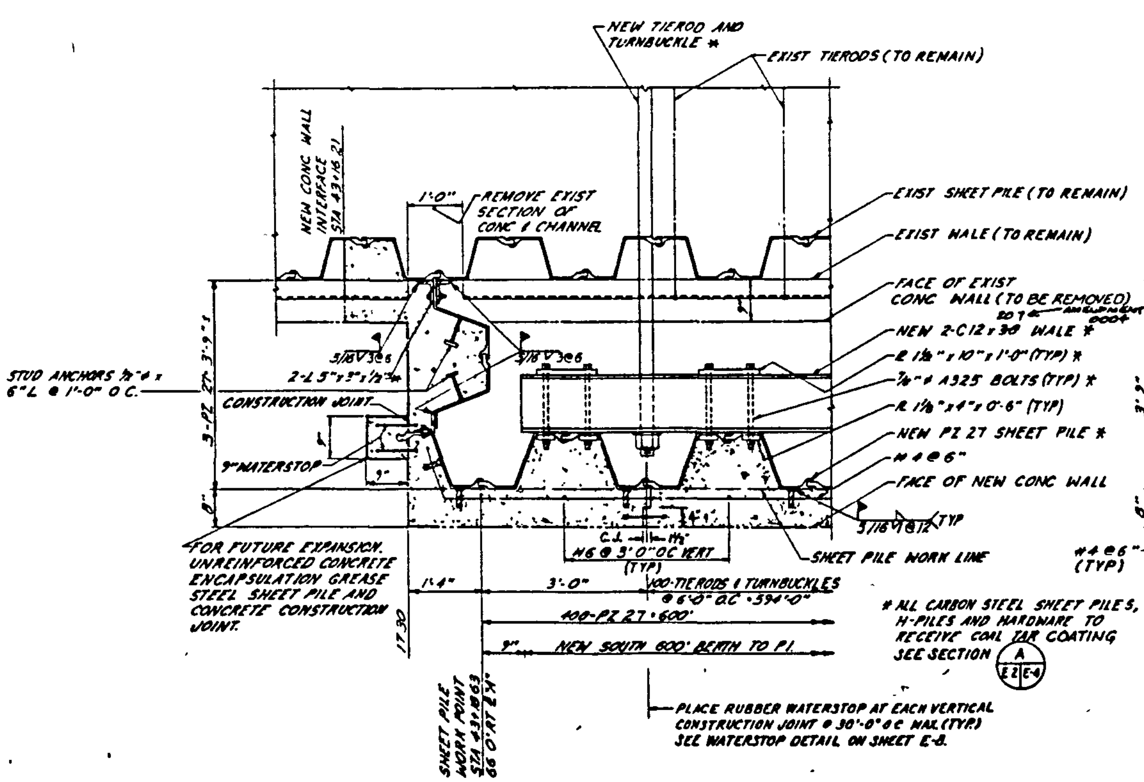


PLAN
SCALE 1" = 20'

TIEROD SYSTEM SCHEDULE				
SYSTEM	ROD DIA (IN)	UPSET DIA (IN)	TURNBUCKLE SIZE	ROD MATERIAL
1	2 3/4	—	2 3/4	A-36
2	2 1/2	2 3/4	2 3/4	A-36
3	2 3/4	—	2 3/4	A-588
4	2 1/2	2 3/4	2 3/4	A-588

NOTE: THE CONTRACTOR SHALL HAVE THE OPTION TO SELECT ONE OF THE FOUR (4) TIEROD SYSTEMS LISTED ABOVE THE SELECTED SYSTEM SHALL NOT BE CHANGED DURING THE COURSE OF WORK.

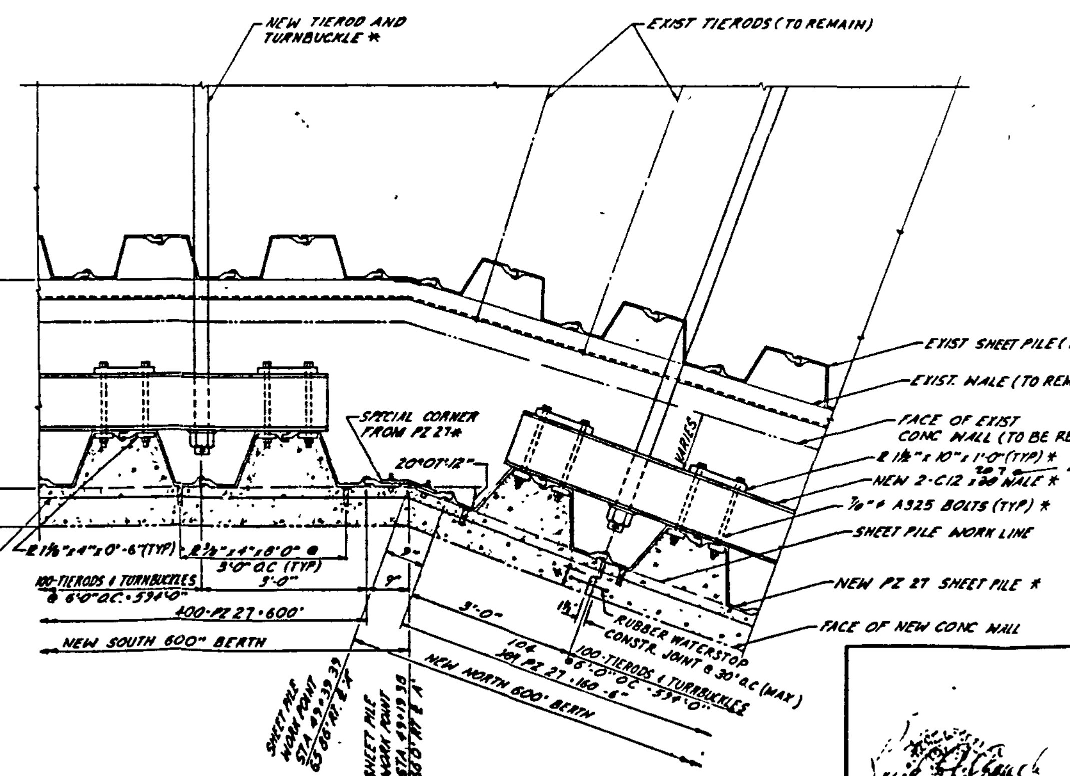
STEEL SHEET PILE SCHEDULE		
STATION		PZ SECTION
FROM	TO	
43+19	51+00	PZ 27 (A572)
51+00	54+81	PZ 38 (A328)
54+81	56+02	PZ 27 (A572)



DETAIL 1
SCALE 3/4" = 1'-0"

* ALL CARBON STEEL SHEET PILES, H-PILES AND HARDWARE TO RECEIVE COAL TAR COATING SEE SECTION A E-4

PLACE RUBBER WATERSTOP AT EACH VERTICAL CONSTRUCTION JOINT @ 30'-0" O.C. MAX (TYP) SEE WATERSTOP DETAIL ON SHEET E-8.



DETAIL 2
SCALE 3/4" = 1'-0"

SCALE: 3/4" = 1'-0"
SCALE: 1" = 20'

REVISIONS				
LET	DESCRIPTION	PREP'D BY	DATE	APPROVED
	DWG. CORRECTED TO AS BUILT			EHD

FOR OFFICIAL USE ONLY

RECORD DRAWING
DATE 11/13/90

Greiner Engineering Sciences, Inc.
CONSULTING ENGINEERS TAMPA, FLORIDA

DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
SOUTHERN DIVISION
CHARLESTON, S.C.

NAVAL AIR STATION KEY WEST, FLA.

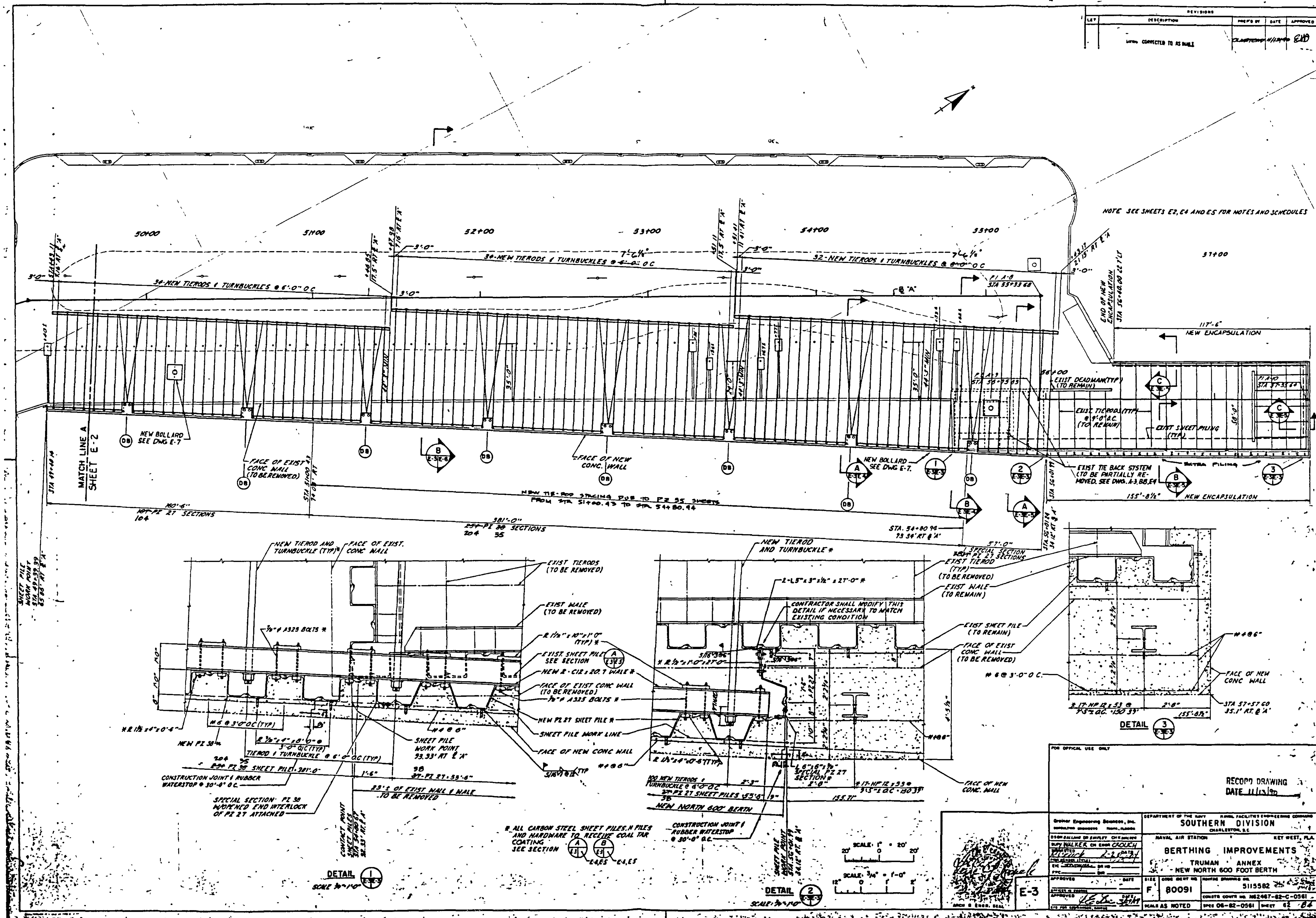
BERTHING IMPROVEMENTS
TRUMAN ANNEX
NEW SOUTH 600 FOOT BERTH

DSGN BALLARD/SHIPLEY CHK WALKER
SUPV WALKER CH ENGR CROUCH

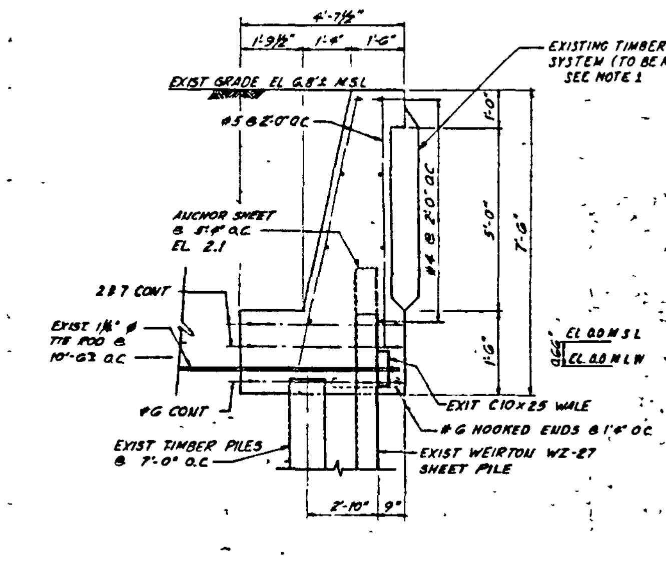
SIZE	CODE IDENT NO	NAVFAC DRAWING NO
F	80091	5115581

CONSTR CONTR NO N62467-82-C-0561
SCALE AS NOTED SPEC 06-82-0561 SHEET 61 84

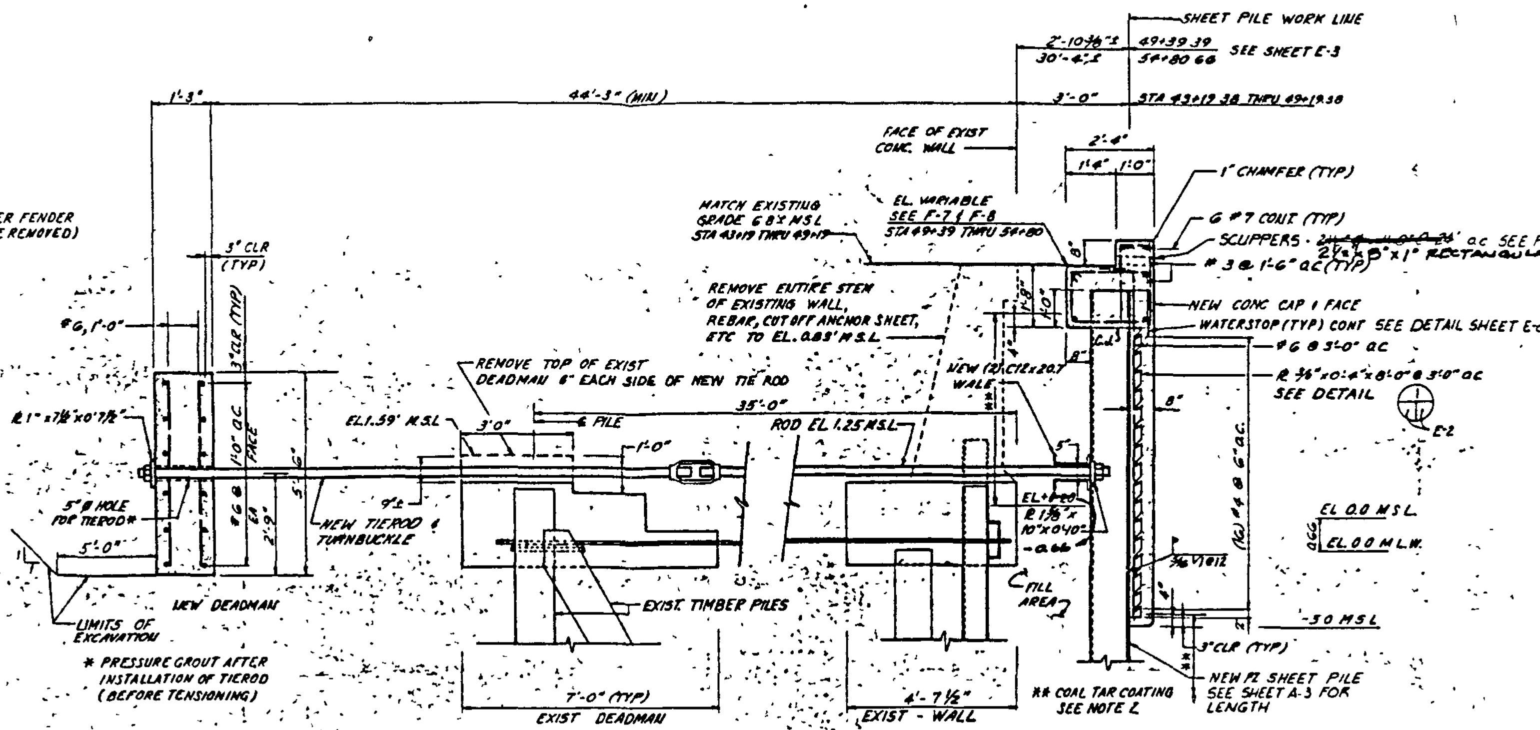
E-2


REVISIONS
LTR DESCRIPTION PREP'D BY DATE APPROVED
CORRECTED TO AS BUILT
NOTE SEE SHEETS E2, E4 AND E5 FOR NOTES AND SCHEDULES
50+00
51+00
52+00
53+00
54+00
55+00
57+00
30-NEW TIERODS & TURNBUCKLES @ 6'-0" O.C.
30-NEW TIERODS & TURNBUCKLES @ 6'-0" O.C
32-NEW TIERODS & TURNBUCKLES @ 6'-0" O.C
MATCH LINE A SHEET E-2
NEW BOLLARD SEE DWG E-7
FACE OF EXIST CONC WALL (TO BE REMOVED)
FACE OF NEW CONC. WALL
NEW BOLLARD SEE DWG E-7.
EXIST DEADMAN (TYP) (TO REMAIN)
EXIST TIERODS (TYP) @ 9'-0" O.C. (TO REMAIN)
EXIST SHEET PILING (TYP)
EXIST TIE BACK SYSTEM (TO BE PARTIALLY REMOVED. SEE DWG. A-3, B8, E4)
117'-6" NEW ENCAPSULATION
155'-8½" NEW ENCAPSULATION
NEW TIE-ROD SPACING DUE TO PZ 35 SHEETS FROM STA 51+00.43 TO STA 54+80.94
160'-6" 104 PZ 27 SECTIONS
381'-0" 204 35 PZ 38 SECTIONS
57'-0" SPECIAL SECTION 38 PZ 27 SECTIONS
NEW TIEROD AND TURNBUCKLE (TYP)
FACE OF EXIST. CONC WALL
EXIST TIERODS (TO BE REMOVED)
EXIST WALE (TO BE REMOVED)
EXIST. SHEET PILE SEE SECTION
NEW 2-C12 x 20.7 WALE
FACE OF EXIST CONC WALL (TO BE REMOVED)
⅞" ϕ A325 BOLTS
NEW PZ 27 SHEET PILE
SHEET PILE WORK LINE
FACE OF NEW CONC WALL
SHEET PILE WORK POINT 93.33' RT ℄ 'A'
CONSTRUCTION JOINT & RUBBER WATERSTOP @ 30'-0" O.C.
SPECIAL SECTION PZ 38 W/OPENED END INTERLOCK OF PZ 27 ATTACHED
TIEROD & TURNBUCKLE @ 6'-0" O.C (TYP)
25'± OF EXIST WALL & WALE TO BE REMOVED
DETAIL 1 SCALE ¾"=1'-0"
NEW TIEROD AND TURNBUCKLE
2-L5" x 3" x ½" x 2'-0"
CONTRACTOR SHALL MODIFY THIS DETAIL IF NECESSARY TO MATCH EXISTING CONDITION
EXIST TIEROD (TYP) (TO BE REMOVED)
EXIST WALE (TO REMAIN)
EXIST SHEET PILE (TO REMAIN)
FACE OF EXIST CONC WALL (TO BE REMOVED)
FACE OF NEW CONC. WALL
100 NEW TIERODS & TURNBUCKLE @ 6'-0" O.C
NEW NORTH 600' BERTH
CONSTRUCTION JOINT & RUBBER WATERSTOP @ 30'-0" O.C.
DETAIL 2 SCALE ¾"=1'-0"
FACE OF NEW CONC WALL
STA 57+57.60 35.1' RT. ℄ 'A'
DETAIL 3
ALL CARBON STEEL SHEET PILES, H PILES AND HARDWARE TO RECEIVE COAL TAR COATING SEE SECTION A B E4,E5
SCALE: 1" = 20'
SCALE: ¾" = 1'-0"
FOR OFFICAL USE ONLY
RECORD DRAWING DATE 11/13/90
Greiner Engineering Sciences, Inc.
DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
SOUTHERN DIVISION
CHARLESTON, S.C.
NAVAL AIR STATION KEY WEST, FLA.
SUPV WALKER CH ENGR CROUCH
BERTHING IMPROVEMENTS
TRUMAN ANNEX
NEW NORTH 600 FOOT BERTH
ARCH & ENGR. SEAL
E-3
SIZE F
CODE IDENT NO 80091
NAVFAC DRAWING NO. 5115582
CONSTR CONTR NO. N62467-82-C-0561
SCALE AS NOTED
SPEC 06-82-0561
SHEET 62 84

REVISIONS			
DESCRIPTION		DATE	APPROVED
DWG. CORRECTED TO AS BUILT		11/13/90	



TYPICAL EXISTING WALL
STA. 49+16 THRU STA. 54+82
SCALE: ½"=1'-0"

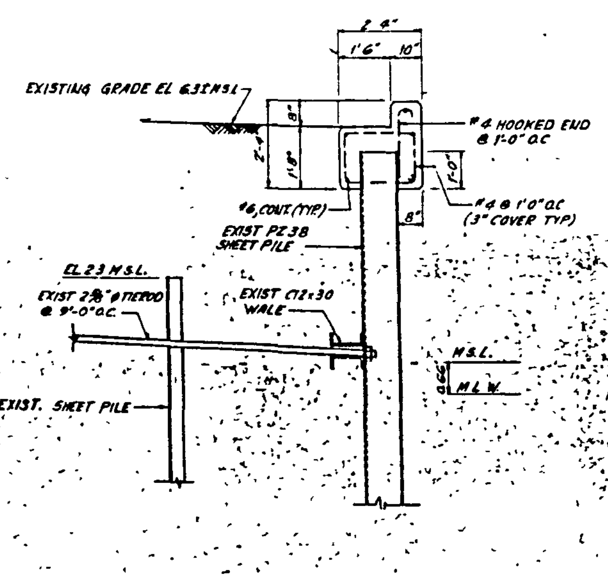


SECTION A (E-4)
SCALE: ½"=1'-0"
E-2, E-3

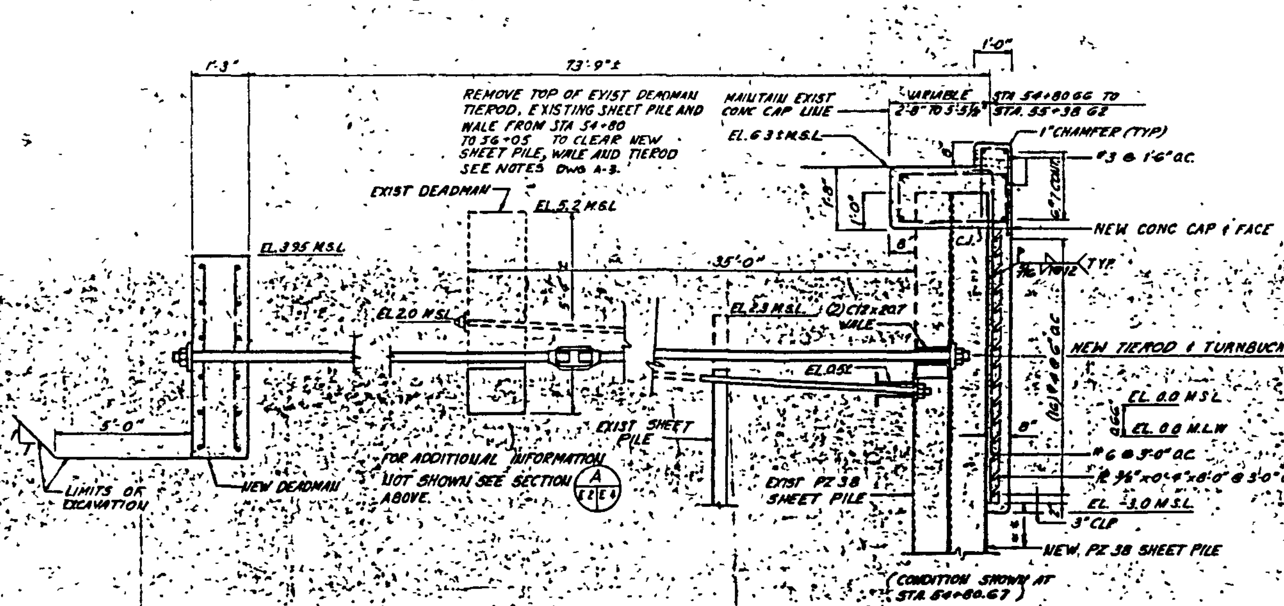
NOTES

1. EXISTING TIMBER FENDER SYSTEM TO BE REMOVED IS SEVERLY DETERIORATED WITH SOME MEMBERS BROKEN OR MISSING. NO SALVAGE VALUE IS EXPRESSED OR IMPLIED BY THESE CONTRACT DOCUMENTS.
2. ALL CARBON STEEL PLATES, BOLTS, NUTS, WASHERS, WALING, STEEL SHEET PILING AND STEEL H-PILING (INCLUDING THOSE ITEMS AT THE DEADMAN ANCHORAGE) SHALL RECEIVE A COAL TAR COATING IN ACCORDANCE WITH SECTION 09805 "COATING SYSTEM (COAL-TAR) FOR SHEET-STEEL PILING" OF THE SPECIFICATIONS EXCEPT AS NOTED BELOW. ALL ITEMS ON THE BACK (LAND) SIDE OF THE BULKHEAD, INCLUDING THE SHEET PILING, ABOVE ELEVATION ~~+0.20~~ -0.66 MSL SHALL RECEIVE THE COATING. THE SHEET PILING AND THE H-PILING SUPPORTING THE CONCRETE ENCAPSULATION SHALL RECEIVE THE COATING FROM ELEVATION -2.67 MSL TO THE TIP ON THE FRONT (WATER) SIDE. THE COATING SHALL BE EXTENDED 4" INTO THE CONCRETE ENCAPSULATION. THE COATING WILL BE APPLIED TO THE SHEET PILING PRIOR TO INSTALLATION WHEN THE AREAS TO RECEIVE THE COATING WILL NOT BE ACCESSABLE OR WHERE THE COATING CANNOT BE PROPERLY APPLIED AFTER THE SHEET PILE HAS BEEN INSTALLED. THE TIE RODS AND TURNBUCKLES SHALL RECEIVE A TAPE WRAPPING SYSTEM AS SPECIFIED IN SECTION 09809, "PROTECTION OF BURIED STEEL BULKHEAD TIE RODS" OF THE SPECIFICATIONS. THE H-PILES IN THE BOLLARD AND DOUBLE BITT FOUNDATIONS SHALL NOT BE COATED.
3. SEE SHEET E-7 FOR DETAILS OF NEW DOUBLE BITTS AND CLEATS.

AMENDMENT 0007
EPOXY



TYPICAL EXISTING WALL
STA. 54+80 THRU STA. 57+57
SCALE ½"=1'-0"



SECTION B (E-3, E-4)
SCALE: ½"=1'-0"

SCALE ½" = 1'-0"

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DATE 11/13/90

Greiner Engineering Sciences, Inc.
CONSULTING ENGINEERS TAMPA, FLORIDA

DSGN BALLARD DR GOUZREE CHK WALKER
SUPV WALKER CH ENGR CROUCH

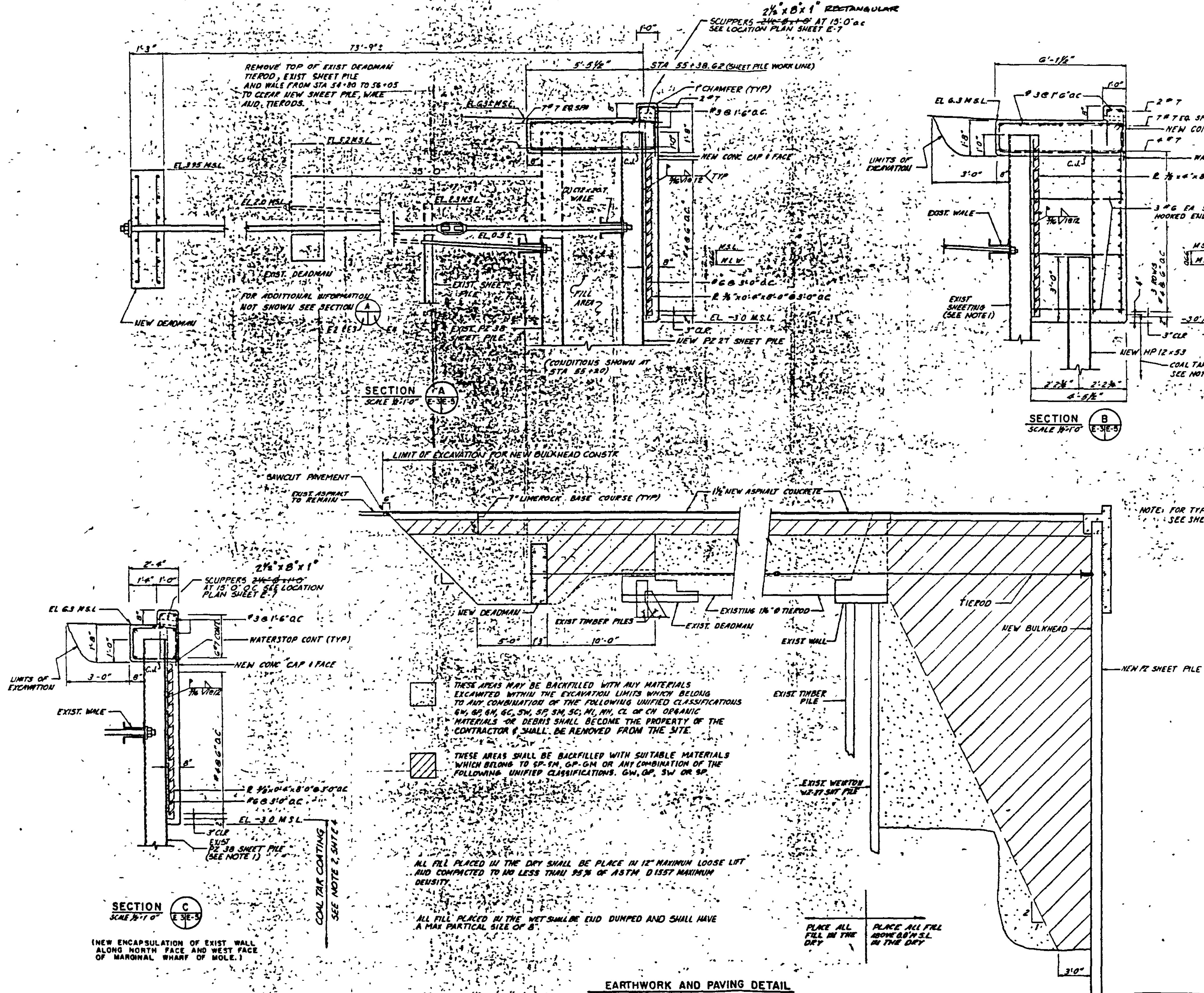
DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
SOUTHERN DIVISION
CHARLESTON S.C.

NAVAL AIR STATION KEY WEST, FLA.
BERTHING IMPROVEMENTS
TRUMAN ANNEX
NEW WALL SECTIONS & DETAILS

E-4

SIZE	CODE IDENT NO	NAVFAC DRAWING NO
F	80091	5115583
		CONSTR CONTR NO N62467-82-C-0561
SCALE ½" = 1'-0"		SPEC 06-82-0561 SHEET 63 84

REVISIONS				
LET	DESCRIPTION	PREP BY	DATE	APPROVED
	DRWG CORRECTED TO AS BUILT			



NOTE

1) ALL EXISTING SHEET PILING TO HAVE NEW CONCRETE ENCAPSULATION SHALL BE CLEANED BY REMOVING ALL LOOSE SCALE, RUST AND MARINE GROWTH DOWN TO BARE METAL

SCALE 1/4" = 1'-0"

SCALE 1/2" = 1'-0"

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Greiner Engineering Sciences, Inc.

DSGN DEPAOLIS-GONZALEZ DR WALKER
SUPV WALKER CH ENGR CROUCH

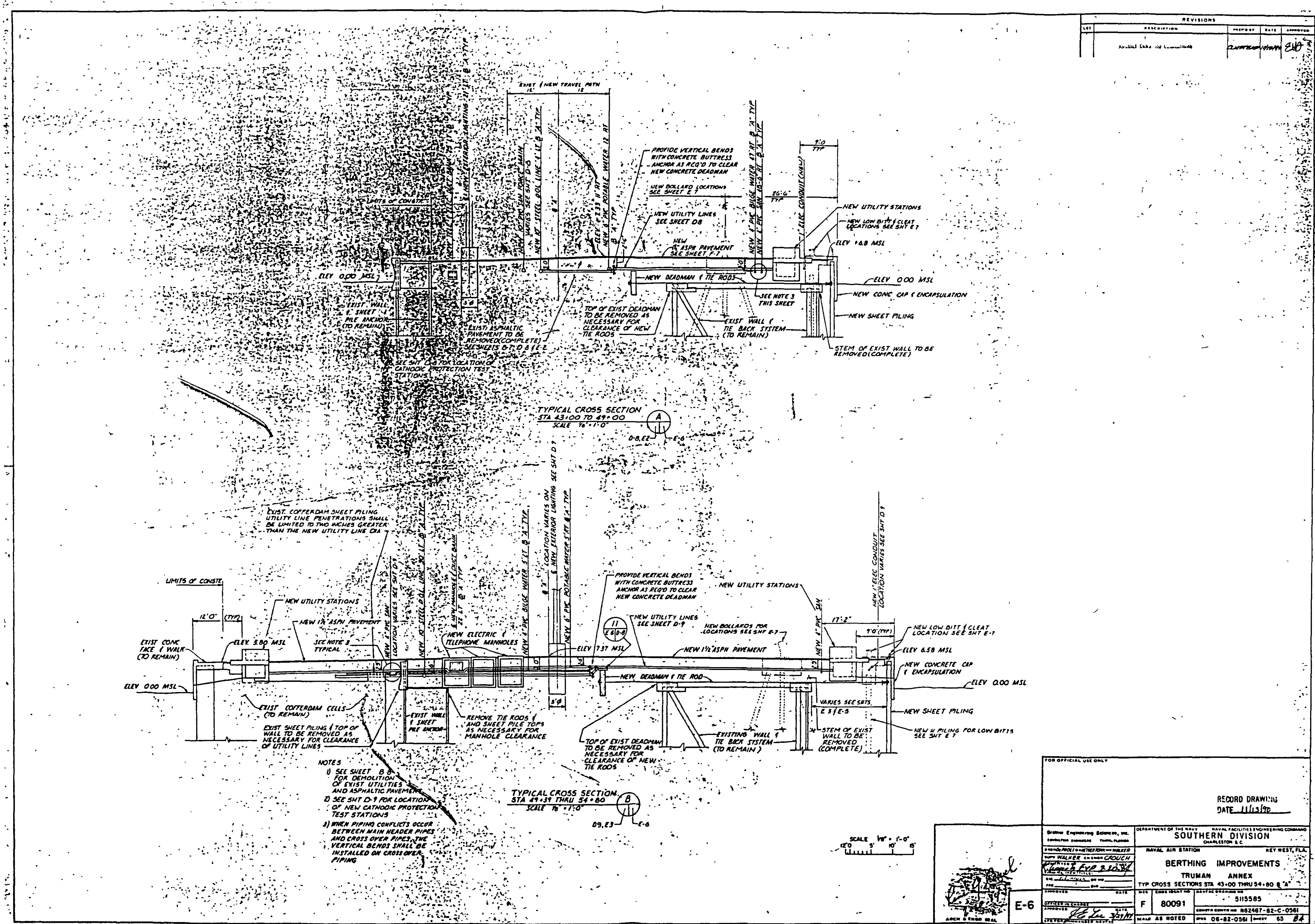
DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
SOUTHERN DIVISION
CHARLESTON S.C.

NAVAL AIR STATION — KEY WEST, FLA.

BERTHING IMPROVEMENTS
TRUMAN ANNEX
NEW WALL SECTIONS & DETAILS

E-5

SIZE	CODE IDENT NO.	NAVFAC DRAWING NO.
F	80091	5115584
		CONSTR CONTR NO N62467-82-C-0561
SCALE AS NOTED		SPEC 06-82-0561 SHEET 64 84


REVISIONS
TYPICAL CROSS SECTION
STA 43+00 TO 49+00
SCALE 1/8" = 1'-0"
PROVIDE VERTICAL BENDS WITH CONCRETE BUTTRESS ANCHOR AS REQ'D TO CLEAR NEW CONCRETE DEADMAN
NEW BOLLARD LOCATIONS SEE SHEET E 7
NEW UTILITY LINES SEE SHEET D8
NEW 1½" ASPH PAVEMENT SEE SHEET F-7
NEW UTILITY STATIONS
NEW LOW BITT & CLEAT LOCATIONS SEE SHT E 7
ELEV +6.8 MSL
ELEV 0.00 MSL
NEW CONC CAP & ENCAPSULATION
NEW SHEET PILING
STEM OF EXIST WALL TO BE REMOVED (COMPLETE)
NEW DEADMAN & TIE RODS
SEE NOTE 3 THIS SHEET
TOP OF EXIST DEADMAN TO BE REMOVED AS NECESSARY FOR CLEARANCE OF NEW TIE RODS
EXIST WALL & TIE BACK SYSTEM (TO REMAIN)
EXIST ASPHALTIC PAVEMENT TO BE REMOVED (COMPLETE) SEE SHEETS B-7, D 8 & E-2
EXIST WALL & SHEET PILE ANCHOR (TO REMAIN)
SEE SHT D-9 FOR LOCATION OF CATHODIC PROTECTION TEST STATIONS
LIMITS OF CONSTR
EXIST & NEW TRAVEL PATH
TYPICAL CROSS SECTION
STA 49+39 THRU 54+80
SCALE 1/8" = 1'-0"
EXIST. COFFERDAM SHEET PILING UTILITY LINE PENETRATIONS SHALL BE LIMITED TO TWO INCHES GREATER THAN THE NEW UTILITY LINE DIA
LIMITS OF CONSTR
NEW UTILITY STATIONS
NEW 1½" ASPH PAVEMENT
EXIST CONC FACE & WALK (TO REMAIN)
ELEV 5.80 MSL
SEE NOTE 3 TYPICAL
ELEV 0.00 MSL
NEW ELECTRIC & TELEPHONE MANHOLES
ELEV 7.37 MSL
PROVIDE VERTICAL BENDS WITH CONCRETE BUTTRESS ANCHOR AS REQ'D TO CLEAR NEW CONCRETE DEADMAN
NEW UTILITY LINES SEE SHEET D-9
NEW BOLLARDS FOR LOCATIONS SEE SHT E-7
NEW 1½" ASPH PAVEMENT
NEW DEADMAN & TIE ROD
NEW LOW BITT & CLEAT LOCATION SEE SHT E-7
ELEV 6.58 MSL
NEW CONCRETE CAP & ENCAPSULATION
ELEV 0.00 MSL
VARIES SEE SHTS. E 3 & E-5
NEW SHEET PILING
NEW H PILING FOR LOW BITTS SEE SHT E 7
STEM OF EXIST WALL TO BE REMOVED (COMPLETE)
EXISTING WALL & TIE BACK SYSTEM (TO REMAIN)
TOP OF EXIST DEADMAN TO BE REMOVED AS NECESSARY FOR CLEARANCE OF NEW TIE RODS
REMOVE TIE RODS & AND SHEET PILE TOPS AS NECESSARY FOR MANHOLE CLEARANCE
EXIST WALL & SHEET PILE ANCHOR
EXIST COFFERDAM CELLS (TO REMAIN)
EXIST SHEET PILING & TOP OF WALL TO BE REMOVED AS NECESSARY FOR CLEARANCE OF UTILITY LINES
NOTES
1) SEE SHEET B 8 FOR DEMOLITION OF EXIST UTILITIES AND ASPHALTIC PAVEMENT
2) SEE SHT D-9 FOR LOCATION OF NEW CATHODIC PROTECTION TEST STATIONS
3) WHEN PIPING CONFLICTS OCCUR BETWEEN MAIN HEADER PIPES AND CROSS OVER PIPES, THE VERTICAL BENDS SHALL BE INSTALLED ON CROSS OVER PIPING
SCALE 1/8" = 1'-0"
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DATE 11/13/90
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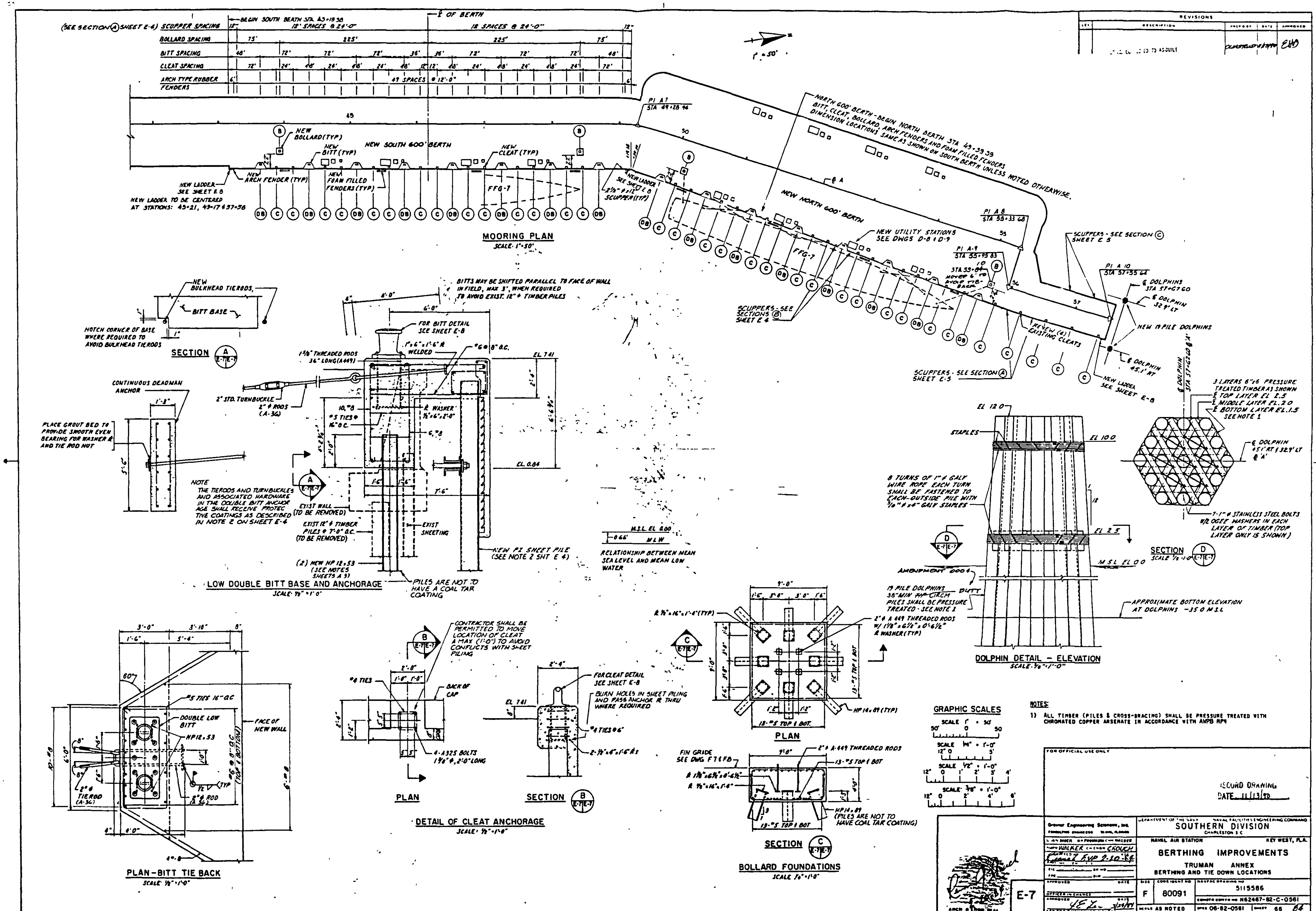
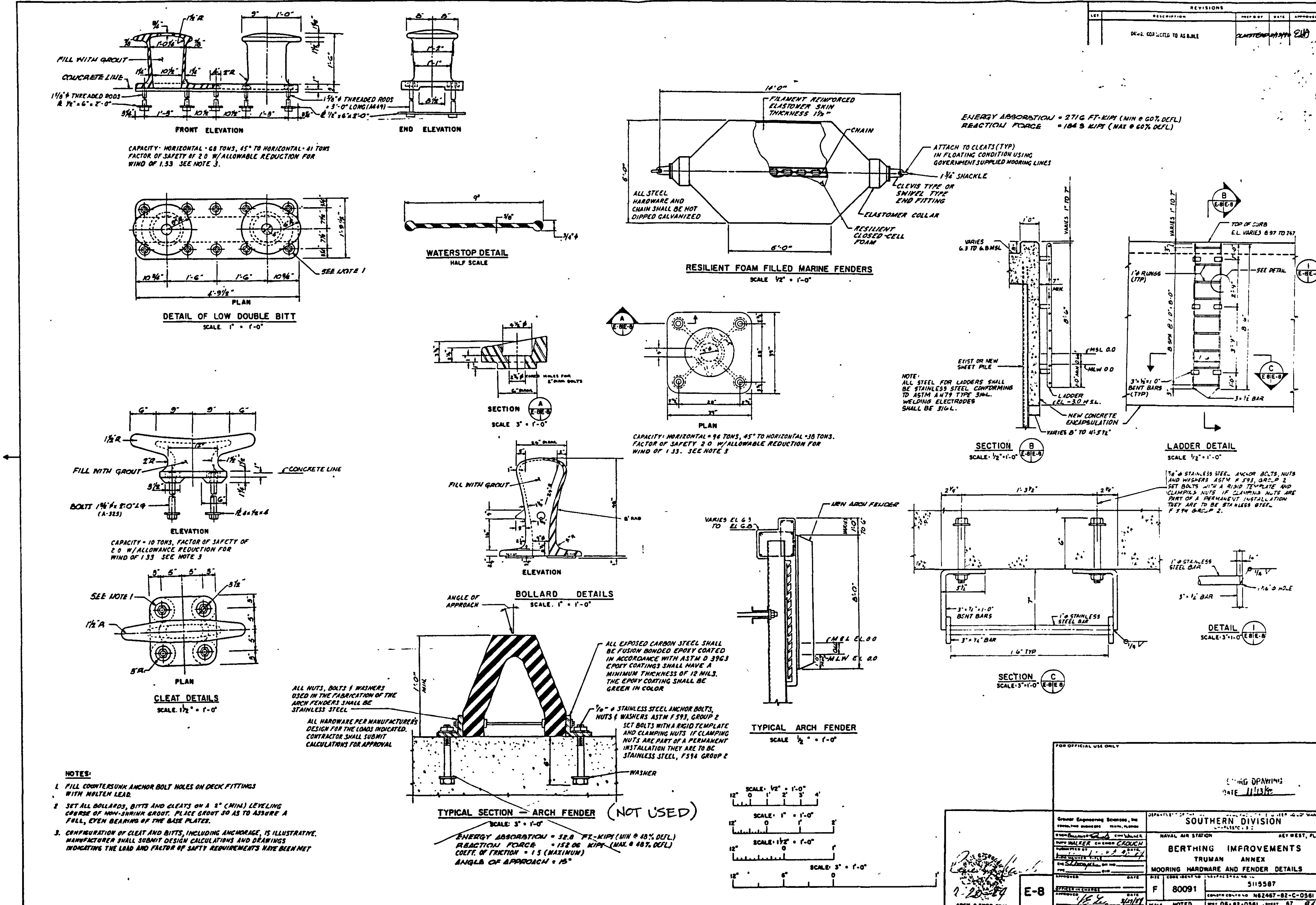
SOUTHERN DIVISION
CHARLESTON S.C.
NAVAL AIR STATION
KEY WEST, FLA.
BERTHING IMPROVEMENTS
TRUMAN ANNEX
TYP CROSS SECTIONS STA 43+00 THRU 54+80 & "A"
E-6
F
80091
5115585
N62467-82-C-0561
AS NOTED
06-82-0561
63
84



REVISIONS
SCUPPER SPACING
BOLLARD SPACING
BITT SPACING
CLEAT SPACING
ARCH TYPE RUBBER FENDERS
BEGIN SOUTH BERTH STA. 43+19.58
℄ OF BERTH
12 SPACES @ 24'-0"
49 SPACES @ 12'-0"
1" = 50'
PI A7 STA 49+28.94
NORTH 600' BERTH - BEGIN NORTH BERTH STA 49+39.39
BITT, CLEAT, BOLLARD, ARCH FENDERS AND FOAM FILLED FENDERS DIMENSION LOCATIONS SAME AS SHOWN ON SOUTH BERTH UNLESS NOTED OTHERWISE.
NEW BOLLARD (TYP)
NEW SOUTH 600' BERTH
NEW BITT (TYP)
NEW CLEAT (TYP)
NEW ARCH FENDER (TYP)
NEW FOAM FILLED FENDERS (TYP)
NEW LADDER SEE SHEET E 8
NEW LADDER TO BE CENTERED AT STATIONS: 43+21, 49+17 & 57+58
NEW NORTH 600' BERTH
NEW UTILITY STATIONS SEE DWGS D-8 & D-9
PI A8 STA 55+33.68
PI A9 STA 55+15.83
PI A10 STA 57+55.64
SCUPPERS - SEE SECTION C SHEET E 5
SCUPPERS - SEE SECTIONS B SHEET E 4
SCUPPERS - SEE SECTION A SHEET E-5
REVIEW (4) EXISTING CLEATS
℄ DOLPHINS STA 57+67.60
NEW 19 PILE DOLPHINS
NEW LADDER SEE SHEET E-8
MOORING PLAN
SCALE: 1" = 50'
NEW BULKHEAD TIERODS
BITT BASE
NOTCH CORNER OF BASE WHERE REQUIRED TO AVOID BULKHEAD TIERODS
SECTION A E-7
BITTS MAY BE SHIFTED PARALLEL TO FACE OF WALL IN FIELD, MAX 3", WHEN REQUIRED TO AVOID EXIST. 12" ⌀ TIMBER PILES
FOR BITT DETAIL SEE SHEET E-8
1 3/8" THREADED RODS 36" LONG (A449)
2" STD. TURNBUCKLE
2" ⌀ RODS (A-36)
CONTINUOUS DEADMAN ANCHOR
PLACE GROUT BED TO PROVIDE SMOOTH EVEN BEARING FOR WASHER ℞ AND TIE ROD NUT
NOTE
THE TIERODS AND TURNBUCKLES AND ASSOCIATED HARDWARE IN THE DOUBLE BITT ANCHORAGE SHALL RECEIVE PROTECTIVE COATINGS AS DESCRIBED IN NOTE 2 ON SHEET E-4
EXIST WALL (TO BE REMOVED)
EXIST 12" ⌀ TIMBER PILES @ 7'-0" O.C. (TO BE REMOVED)
EXIST SHEETING
(2) NEW HP 12x53 (SEE NOTES SHEETS A 3)
NEW PZ SHEET PILE (SEE NOTE 2 SHT E 4)
PILES ARE NOT TO HAVE A COAL TAR COATING
LOW DOUBLE BITT BASE AND ANCHORAGE
SCALE: 1/2" = 1'-0"
M.S.L. EL 0.00
MLW
RELATIONSHIP BETWEEN MEAN SEA LEVEL AND MEAN LOW WATER
3 LAYERS 6"x6 PRESSURE TREATED TIMBER AS SHOWN
TOP LAYER EL 2.5
MIDDLE LAYER EL 2.0
BOTTOM LAYER EL 1.5
SEE NOTE 1
STAPLES
8 TURNS OF 1" ⌀ GALV WIRE ROPE EACH TURN SHALL BE FASTENED TO EACH OUTSIDE PILE WITH 3/8" ⌀ x4" GALV STAPLES
7-1" ⌀ STAINLESS STEEL BOLTS W/2 OGEE WASHERS IN EACH LAYER OF TIMBER (TOP LAYER ONLY IS SHOWN)
SECTION D
19 PILE DOLPHINS 36" MIN CIRCM PILES SHALL BE PRESSURE TREATED - SEE NOTE 1
APPROXIMATE BOTTOM ELEVATION AT DOLPHINS -35.0 M.S.L.
DOLPHIN DETAIL - ELEVATION
CONTRACTOR SHALL BE PERMITTED TO MOVE LOCATION OF CLEAT A MAX (1'-0") TO AVOID CONFLICTS WITH SHEET PILING
FOR CLEAT DETAIL SEE SHEET E-8
BURN HOLES IN SHEET PILING AND PASS ANCHOR ℞ THRU WHERE REQUIRED
4-A325 BOLTS 1 1/8" ⌀, 2'-0" LONG
PLAN
SECTION B
DETAIL OF CLEAT ANCHORAGE
SCALE: 1/2" = 1'-0"
DOUBLE LOW BITT
HP12x53
FACE OF NEW WALL
2" ⌀ TIEROD (A-36)
PLAN - BITT TIE BACK
SCALE: 1/2" = 1'-0"
2" ⌀ A 449 THREADED RODS
HP 14x89 (TYP)
PLAN
FIN GRADE SEE DWG F7 & F8
13-#5 TOP & BOT
HP14x89 (PILES ARE NOT TO HAVE COAL TAR COATING)
SECTION C
BOLLARD FOUNDATIONS
GRAPHIC SCALES
NOTES:
1) ALL TIMBER (PILES & CROSS-BRACING) SHALL BE PRESSURE TREATED WITH CHROMATED COPPER ARSENATE IN ACCORDANCE WITH AWPB MP4
RECORD DRAWING DATE 11/13/90
DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
SOUTHERN DIVISION
CHARLESTON S.C.
NAVAL AIR STATION KEY WEST, FLA.
BERTHING IMPROVEMENTS
TRUMAN ANNEX
BERTHING AND TIE DOWN LOCATIONS
E-7
F 80091
5115586
N62467-82-C-0561
SCALE AS NOTED
SPEC 06-82-0561
SHEET 66 64



REVISIONS
DRWG. CORRECTED TO AS BUILT
FILL WITH GROUT
CONCRETE LINE
1 1/8" ϕ THREADED RODS
FRONT ELEVATION
END ELEVATION
CAPACITY: HORIZONTAL - 68 TONS, 45° TO HORIZONTAL - 41 TONS FACTOR OF SAFETY OF 2.0 W/ ALLOWABLE REDUCTION FOR WIND OF 1.33 SEE NOTE 3.
SEE NOTE 1
PLAN
DETAIL OF LOW DOUBLE BITT
SCALE 1" = 1'-0"
WATERSTOP DETAIL
HALF SCALE
FILAMENT REINFORCED ELASTOMER SKIN THICKNESS 1 1/2"
CHAIN
ATTACH TO CLEATS (TYP) IN FLOATING CONDITION USING GOVERNMENT SUPPLIED MOORING LINES
1 3/4" SHACKLE
CLEVIS TYPE OR SWIVEL TYPE END FITTING
ELASTOMER COLLAR
RESILIENT CLOSED CELL FOAM
ALL STEEL HARDWARE AND CHAIN SHALL BE HOT DIPPED GALVANIZED
RESILIENT FOAM FILLED MARINE FENDERS
SCALE 1/2" = 1'-0"
ENERGY ABSORPTION = 271.6 FT-KIPS (MIN @ 60% DEFL)
REACTION FORCE = 184.8 KIPS (MAX @ 60% DEFL)
SECTION A
SCALE 3" = 1'-0"
CAPACITY: HORIZONTAL = 94 TONS, 45° TO HORIZONTAL = 38 TONS. FACTOR OF SAFETY 2.0 W/ ALLOWABLE REDUCTION FOR WIND OF 1.33. SEE NOTE 3
FILL WITH GROUT
ELEVATION
BOLLARD DETAILS
SCALE 1" = 1'-0"
NOTE: ALL STEEL FOR LADDERS SHALL BE STAINLESS STEEL CONFORMING TO ASTM A479 TYPE 316L. WELDING ELECTRODES SHALL BE 316L.
EXIST OR NEW SHEET PILE
LADDER EL -3.0 MSL
NEW CONCRETE ENCAPSULATION
SECTION B
SCALE 1/2" = 1'-0"
TOP OF CURB
1" ϕ RUNGS (TYP)
SEE DETAIL
BENT BARS (TYP)
LADDER DETAIL
SCALE 1/2" = 1'-0"
FILL WITH GROUT
CONCRETE LINE
BOLTS 1 3/8" ϕ x 2'-0" LG (A-325)
ELEVATION
CAPACITY = 10 TONS, FACTOR OF SAFETY OF 2.0 W/ ALLOWANCE REDUCTION FOR WIND OF 1.33 SEE NOTE 3
SEE NOTE 1
PLAN
CLEAT DETAILS
SCALE 1 1/2" = 1'-0"
NEW ARCH FENDER
MSL EL 0.0
MLW EL 0.0
TYPICAL ARCH FENDER
SCALE 1/2" = 1'-0"
7/8" ϕ STAINLESS STEEL ANCHOR BOLTS, NUTS AND WASHERS ASTM F 593, GROUP 2 SET BOLTS WITH A RIGID TEMPLATE AND CLAMPING NUTS. IF CLAMPING NUTS ARE PART OF A PERMANENT INSTALLATION THEY ARE TO BE STAINLESS STEEL F 594 GROUP 2.
1" ϕ STAINLESS STEEL BAR
3" x 1/2" BAR
SECTION C
SCALE 3" = 1'-0"
DETAIL 1
SCALE 3" = 1'-0"
ANGLE OF APPROACH
ALL EXPOSED CARBON STEEL SHALL BE FUSION BONDED EPOXY COATED IN ACCORDANCE WITH ASTM D 3963. EPOXY COATINGS SHALL HAVE A MINIMUM THICKNESS OF 12 MILS. THE EPOXY COATING SHALL BE GREEN IN COLOR
ALL NUTS, BOLTS & WASHERS USED IN THE FABRICATION OF THE ARCH FENDERS SHALL BE STAINLESS STEEL
ALL HARDWARE PER MANUFACTURER'S DESIGN FOR THE LOADS INDICATED. CONTRACTOR SHALL SUBMIT CALCULATIONS FOR APPROVAL
7/8" ϕ STAINLESS STEEL ANCHOR BOLTS, NUTS & WASHERS ASTM F 593, GROUP 2 SET BOLTS WITH A RIGID TEMPLATE AND CLAMPING NUTS. IF CLAMPING NUTS ARE PART OF A PERMANENT INSTALLATION THEY ARE TO BE STAINLESS STEEL, F594 GROUP 2
WASHER
TYPICAL SECTION - ARCH FENDER (NOT USED)
SCALE: 3" = 1'-0"
ENERGY ABSORPTION = 52.8 FT-KIPS (MIN @ 48% DEFL.)
REACTION FORCE = 152.06 KIPS (MAX @ 48% DEFL)
COEFF. OF FRICTION = 1.5 (MAXIMUM)
ANGLE OF APPROACH = 15°
NOTES:
1. FILL COUNTERSUNK ANCHOR BOLT HOLES ON DECK FITTINGS WITH MOLTEN LEAD.
2. SET ALL BOLLARDS, BITTS AND CLEATS ON A 2" (MIN) LEVELING COURSE OF NON-SHRINK GROUT. PLACE GROUT SO AS TO ASSURE A FULL, EVEN BEARING OF THE BASE PLATES.
3. CONFIGURATION OF CLEAT AND BITTS, INCLUDING ANCHORAGE, IS ILLUSTRATIVE. MANUFACTURER SHALL SUBMIT DESIGN CALCULATIONS AND DRAWINGS INDICATING THE LOAD AND FACTOR OF SAFETY REQUIREMENTS HAVE BEEN MET
SCALE: 1/2" = 1'-0"
SCALE: 1" = 1'-0"
SCALE: 1 1/2" = 1'-0"
SCALE: 3" = 1'-0"
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DATE 11/13/89
Greiner Engineering Sciences, Inc.
WALKER
CROUCH
ARCH & ENGR SEAL
E-8
SOUTHERN DIVISION
NAVAL AIR STATION
KEY WEST, FLA
BERTHING IMPROVEMENTS
TRUMAN ANNEX
MOORING HARDWARE AND FENDER DETAILS
F
80091
5115587
N62467-82-C-0561
NOTED
06-82-0561
67
86

APPENDIX C

FIELD HYDRAULIC TEST OF A RECTANGULAR ENCLOSURE COMPRISED OF BETHLEHEM STEEL PZ22 SHEET PILING

FIELD HYDRAULIC TEST OF A RECTANGULAR ENCLOSURE COMPRISED OF BETHLEHEM STEEL PZ22 SHEET PILING*

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N2L 3G1

INTRODUCTION

Low hydraulic conductivity cutoff walls can be used in a variety of applications for remediation of sites with subsurface contamination. In particular, they are useful for isolating contaminant source zones that generate plumes of contaminated groundwater, and for improving the efficiency of pump-and-treat systems that control migration of these plumes. These applications are described by Starr and Cherry (1992). A cutoff wall acts as a barrier to groundwater flow. The parameter 'hydraulic conductivity' describes the ability of a material to transmit water. With all other things being equal, the effectiveness of a cutoff wall as a flow barrier increases with decreasing hydraulic conductivity, so it is desirable for the hydraulic conductivity of a cutoff wall to be as low as possible.

Steel sheet piling is commonly used to construct cutoff walls for civil engineering applications. However, it is less commonly used for environmental control or remediation applications, in part because there is a common perception that leakage through the joints renders sheet pile cutoff walls too permeable. A project undertaken by the University of Waterloo and Bethlehem Steel Corporation to measure the hydraulic conductivity of a cutoff wall constructed of steel sheet piling manufactured by Bethlehem Steel is described in this report.

To measure the hydraulic conductivity of the cutoff wall, a rectangular cell was constructed using steel sheet piling. The sheet pile cutoff walls extend through a surficial aquifer and into an underlying aquitard, which forms the bottom of the cell. The hydraulic conductivity of the cutoff walls that form the sides of the cell was measured by a field hydraulic test. The test procedure involves displacing the water table in the cell interior from the equilibrium level and observing the rate at which it returns to the equilibrium level, which depends on the hydraulic conductivity of the cutoff walls. Computer simulations of the water level recovery were made using a range of hydraulic conductivity values. The hydraulic conductivity value that gives the best fit of the simulated response to the observed data is taken as the hydraulic conductivity of the cutoff wall.

* PZ22, PZ27, PZ35, PZ40, PLZ23, and PLZ25 hot-rolled ball & socket interlocks have similar dimensions. Therefore, the University of Waterloo's findings are valid for all Bethlehem Steel Z-piling sections.

SITE DESCRIPTION AND FACILITIES

The test cell was constructed at a University of Waterloo research site at Canadian Forces Base Borden, which is about 100 km north of Toronto, Ontario. The cell is situated in an abandoned sand quarry that is the site of numerous groundwater experiments and hence is well characterized. The geologic materials present at the cell are shown in Figure 1, which was generated using data from several boreholes in the immediate vicinity of the test cell. The sheet pile walls extend through the surficial sandy aquifer into the underlying silt and clay aquitard.

The cutoff walls consist of Bethlehem Steel PZ22 steel sheet piling. Each sheet is 0.375 inches (0.953 cm) thick, and 50 feet (15.2 m) long. The cell is shown in plan view in Figure 2.

The elevations of the water table inside the cell and adjacent to the cell were measured during the hydraulic tests. Two reference points were established for this purpose. The first is a pair of parallel lines filed atop the sheet piling at the northeast corner of the cell. The second is a similar mark established at the top of casing of observation well EW-1, which is adjacent to the north end of the cell. The elevation of both reference points was determined relative to an arbitrary local elevation datum, and hence elevations or hydraulic head values are reported herein as metres above local datum (m ald). The water table elevation inside the cell was determined by measuring the vertical distance from the reference point atop the cell to the water surface inside the cell using a Solinst Model 101 water level tape (Solinst Canada Ltd., Glen Williams, Ontario), and subtracting this distance from the reference point elevation. A similar procedure was used to determine the water table elevation in well EW-1.

HYDRAULIC TEST PROCEDURE

Two hydraulic tests were conducted using the same procedure. Under conditions of hydraulic equilibrium, the elevation of the water table inside the cell will be the same as the elevation of the water table outside of and adjacent to the cell. If the interior water table is displaced from the equilibrium position, for example by pumping water out of the cell, groundwater will flow through the sides of the cell until hydraulic equilibrium is reestablished. The rate of recovery to equilibrium is a function of the hydraulic conductivity of the cutoff walls, cell geometry, and the magnitude of the difference in hydraulic head (i.e. water table elevation) between the inside and outside of the cell.

The hydraulic tests were conducted by pumping water from the interior of the test cell to lower the interior water table below the water table outside the cell. To be consistent with the assumptions of the computer model used for interpreting the test, the interior water table could not be lowered below the ground surface inside the cell. The interior ground surface settled while the sheet piles were being driven, and prior to the test the ground surface inside the cell was levelled. This allowed the interior water level to be lowered below the exterior water table and still be above the interior ground surface. After the interior water table was lowered, the depth to the interior and exterior water tables was observed until recovery of approximately 90 percent was achieved.

To allow the interior water table to be lowered further yet still remain above ground surface, which leads to data set with less measurement error, soil was excavated from the upper two metres of the cell interior before the second hydraulic test. The second hydraulic test was then carried out using the same procedure described above.

COMPUTER MODEL

A computer model was developed to simulate the hydraulic recovery (i.e. the return of the interior water table to its equilibrium value). The model is based on the following assumptions:

1. Water flows through the sides of the cell, but not through the bottom;

2. Flow through the cutoff walls can be described by the Darcy equation

$$Q = - K_{wall} A_{wall} (\text{delta } H / b_{wall})$$

where	Q	volume discharge into the cell
	K_{wall}	hydraulic conductivity of the wall
	A_{wall}	area of the wall that transmits water
	delta H	difference in hydraulic head between the inside and outside of the cell
	b_{wall}	thickness of the wall

3. At any time, the hydraulic head inside the cell is at a uniform value throughout the cell;

4. At any time, the water table adjacent to the cell is at a constant elevation, which is the same as the water table elevation measured in observation well EW-1;

5. A single value of hydraulic conductivity applies to the entire cutoff wall;

6. The portion of the cell wall below the exterior water table and above the interior water table can be treated as a seepage face;

7. The portion of the wall that transmits water extends from the exterior water table to the top of the clay layer;

8. The water table inside the cell is above the ground surface inside the cell throughout the test.

Assumption 1 will cause the calculated value of hydraulic conductivity of the cutoff wall to be greater than the actual value if leakage through the bottom occurs. Given the distance that the cutoff walls extend into low hydraulic conductivity materials at the bottom of the cell, it is unlikely that significant flow through the bottom of the cell occurred.

The calculated value of hydraulic conductivity is inversely proportional to the depth of the wall that is assume to transmit water (see assumption 7). In the situation here, the water transmitting portion of the wall was assumed to extend to the top of the clay layer. The other reasonable assumption is that the water transmitting portion of the wall extends only to the bottom of the sand layer. The hydraulic conductivity value that gives the best fit to the test data differ by a factor of approximately two for these two assumptions. Given that hydraulic conductivity values observed in hydraulic tests of cutoff walls range over about six orders of magnitude (i.e. a factor of one million), a difference of two is negligible.

Assumption 8 is made to circumvent uncertainties in the value of specific yield, which varies dramatically when the water table is slightly below ground surface. If the water table is above ground surface, specific yield is one.

RESULTS AND DISCUSSION

The observed water table elevation data inside and outside the cell during the first hydraulic test in April 1992 are shown in Figure 3. The exterior water table fluctuated between approximately 98.4 and 98.5 metres above local datum over two days due to variation in infiltration and recharge rates. The interior water table was pumped down approximately 0.45 m at the start of the test and recovered approximately 89 percent during two days. Simulated response curves for a variety of hydraulic conductivity values are also shown. (The labels are in the format 1 E-8 cm/s, which is equivalent to 1×10^{-8} cm/s.) The hydraulic conductivity value that gives the best fit to the observed data is 5×10^{-7} cm/s.

A second hydraulic test was conducted in December 1992. The interior of the cell was excavated so the interior water table could be lowered farther yet still be above the interior ground surface. This allows the difference between the interior and exterior water tables to be larger relative to the fluctuations in the exterior water table, which facilitates collection of a smoother data set. Figure 4 shows the observed interior and exterior water table elevations and the simulated response. The exterior water table fluctuated only 0.025 m during the second hydraulic test, compared to 0.1 m during the first test. This reflects the less dynamic character of the hydrologic system during the late fall compared to early spring. The interior water table was lowered 1.76 metres at the start of the test, and 92 percent recovery occurred during eight days. Given the smaller fluctuations in the exterior water table, the larger head difference imposed at the start of the test, and the more uniform distribution of observations, the second data set is thought to be of higher quality than the first.

The hydraulic conductivity value that gives the best fit to the data is 1.5×10^{-7} cm/s. The best fit value from the first test, 5×10^{-7} cm/s, is slightly greater than the best fit value from the second test. The cause of this discrepancy is not known. Given the wide range of hydraulic conductivity values observed in tests of cutoff wall enclosures, the discrepancy of 3.3 observed here is not considered to be important.

In a previous study conducted by the University of Waterloo, the hydraulic conductivity of a cutoff wall constructed of cold-rolled sheet piling was found to be 10^{-4} cm/s, about 700 times as large as the value observed here. This indicates that the hot rolled sheet piling used in this test is a more effective barrier to groundwater flow than the cold rolled sheet piling used in the previous test.

Given that the leakage through a sheet pile cutoff walls occurs through the joints, the amount of leakage through the joints and hence the hydraulic conductivity of the cutoff wall as a whole can be reduced by sealing the joints. Starr et al. (1992) discuss the magnitude of the hydraulic conductivity decrease that can be achieved by joint sealing. Cells similar to the one described here have been constructed using sheet piling with sealed joints. Various sealants were used in different cells. The cells were subjected to hydraulic tests similar to the one described here. Hydraulic conductivity values observed in these tests typically range from 10^{-8} cm/s to 10^{-10} cm/s. The differences between the various cells is thought to reflect mainly differences in the sealant materials used. Sealed joint sheet pile cutoff walls evaluated in that series of tests are approximately 100 to 10,000 times more effective as groundwater flow barriers than the hot rolled sheet piling with conventional unsealed joints evaluated in this test.

SUMMARY

The hot rolled steel sheet piling with conventional unsealed joints (Bethlehem Steel PZ22) evaluated in this hydraulic test has a hydraulic conductivity of 1.5-5 X 10^{-7} cm/s. It is substantially less permeable than conventional cold rolled sheet piling evaluated in a separate test, but more permeable than sheet piling with joints that are sealed after installation.

REFERENCES

Starr, R.C., and J.A. Cherry, 1992. Applications of low permeability cutoff walls for groundwater pollution control. 45th Canadian Geotechnical Conference, October 26-28, Toronto, Ontario.

Starr, R.C., J.A. Cherry, and E.S. Vales, 1992. A new type of steel sheet piling with sealed joints for groundwater pollution control. 45th Canadian Geotechnical Conference, October 26-28, toronto, Ontario.

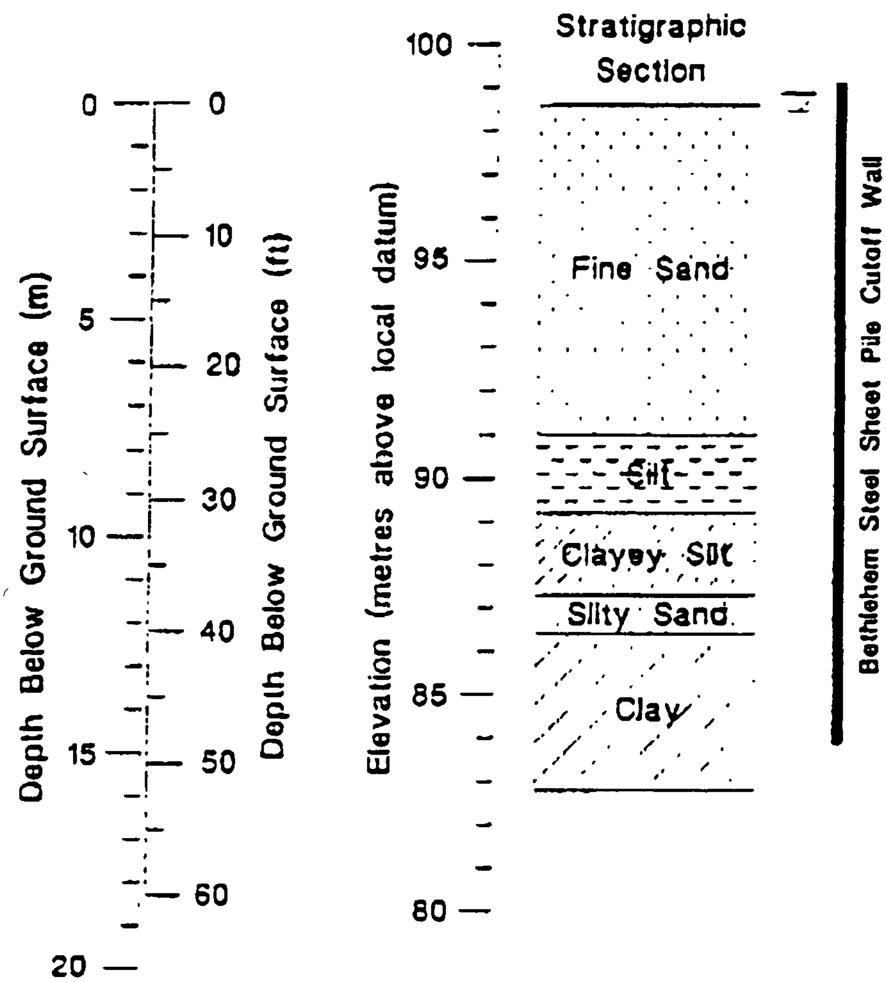

Figure 1
Stratigraphic section at the test cell site

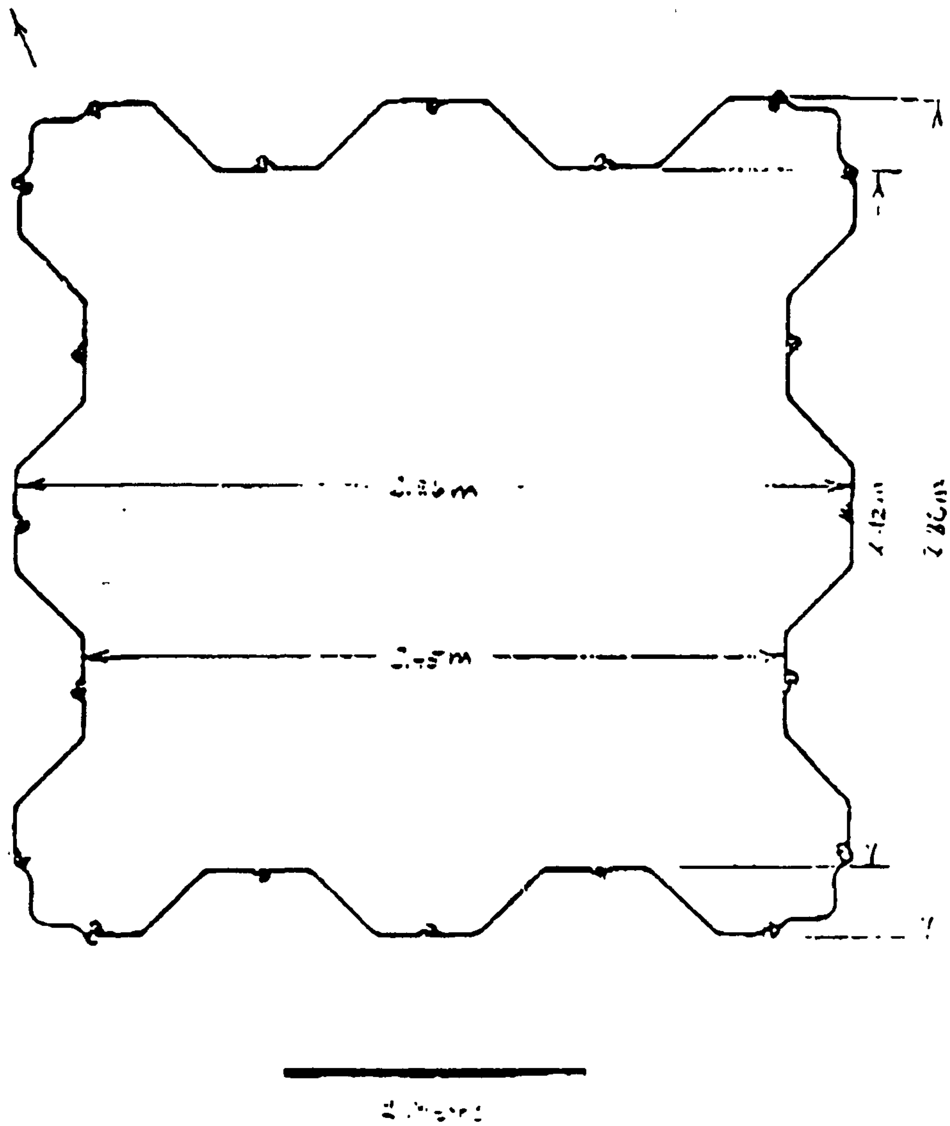

Figure 2
Plan view of the test cell

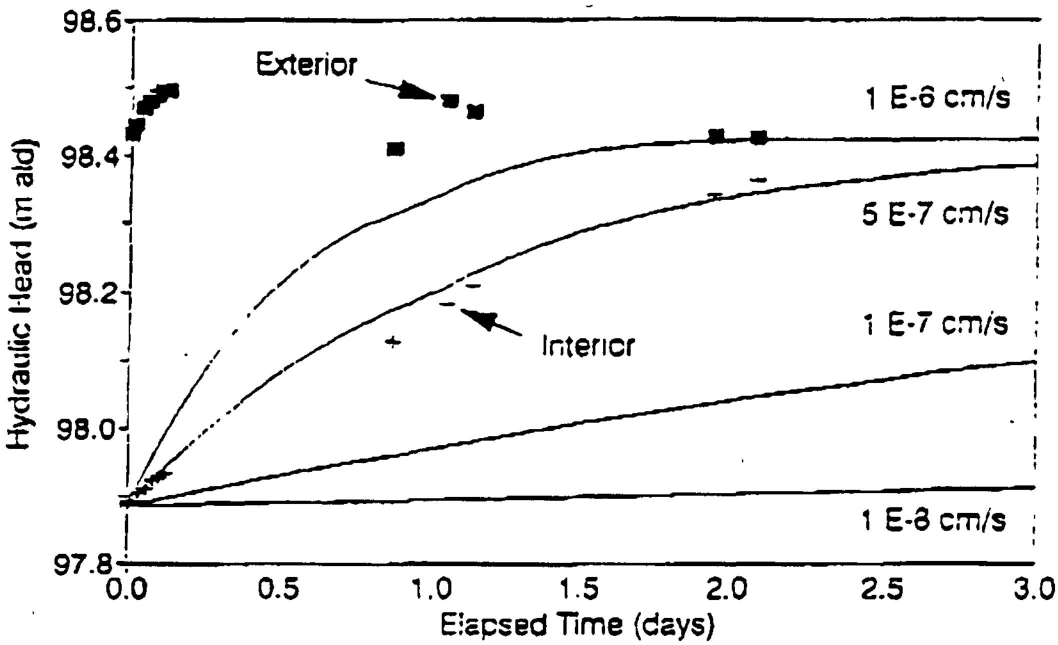

Figure 3
Experimental results and simulated response: April 1992 test

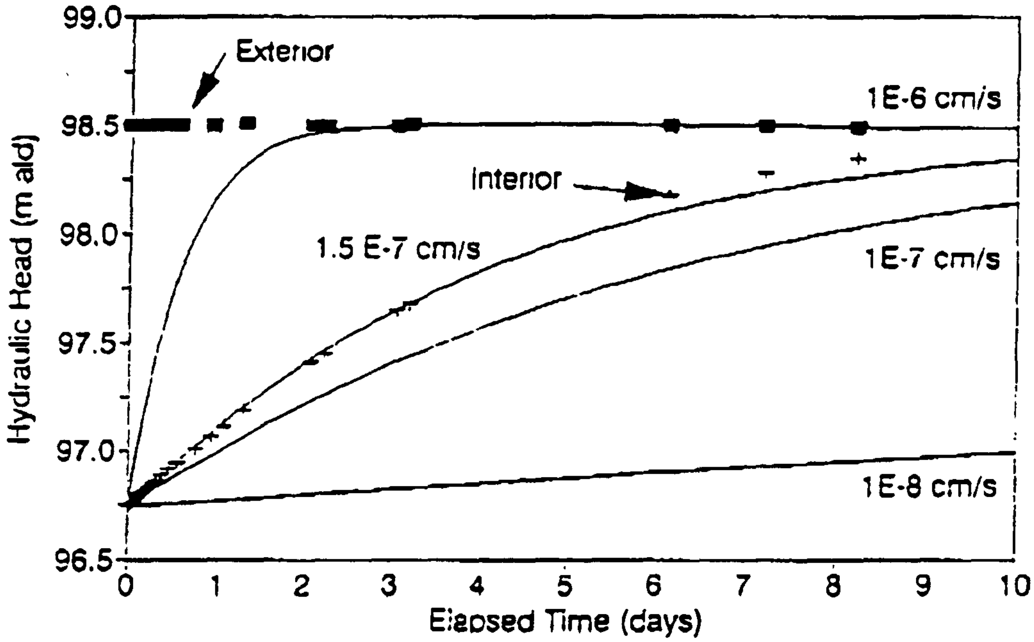

Figure 4
Experimental results and simulated response: December 1992 test

APPENDIX D

FDEP COMMENTS DATED NOVEMBER 14, 1994
ABB ENVIRONMENTAL SERVICES, INC., (ABB-ES) RESPONSES
DATED JANUARY 1995

Department of
Environmental Protection

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Lawton Chiles
Governor

Virginia B. Wetherell
Secretary

November 14, 1994

Mr. Gabriel Magwood, Code 1849
Southern Division
Naval Facilities Engineering Command
PO Box 190010
North Charleston, S.C. 29419-9010

RE: Remedial Action Plan for Site 103.
Naval Air Station Key West

Dear Mr. Magwood:

The Department has reviewed the Draft Remedial Action Plan for Site 103, dated August 1994 (received October 18, 1994). Enclosed are comments from Greg Brown on the report. The comments must be adequately addressed in an addendum to the RAP.

In case of any assistance in this matter, please contact me or Greg Brown at 904/488-3935.

Sincerely,

Jorge R. Caspary

Jorge R. Caspary, P.G.
Remedial Project Manager

Enclosures

cc: Michael K. Dunaway, ABB-Tallahassee
Bill Carlye, NAS Key West
Mark Diblin, ABB-Tallahassee

TJB ___ JJC JJC ESN ESN

"Protect, Conserve and Manage Florida's Environment and Natural Resources"

Printed on recycled paper.

Florida Department of

Environmental Protection

Memorandum

TO: Jorge Caspary, P.G., Remedial Project Manager, Technical Review Section

THROUGH: Tim Bahr, P.G., Supervisor, Technical Review Section TB

FROM: Greg Brown, P.E. II, Technical Review Section GB

DATE: October 26, 1994

SUBJECT: Remedial Action Plan for Site 103 at Truman Annex for Naval Air Station, Key West, Florida, August 1994.

I have reviewed the subject document and my specific comments are attached. I recommend that the Navy proceed with the limited soil and free product removal described in the RAP as an interim remedial action. Other important issues remain outstanding, however. The Navy must adequately address them before the RAP can be approved. These include:

- provide sufficient justification that all pathways to potential receptors under likely exposure scenarios have been eliminated;
- provide adequate evidence that the bulkhead is impermeable; and
- prepare and implement a monitoring plan.

The limited remedial action proposed in the RAP may be justified if a better effort is made in the document to show that weak exposure pathways exist under likely exposure scenarios. The impermeability of the bulkhead is also a critical issue since there may be a direct link between contaminated ground water and receiving surface water bodies. Because contaminated ground water and excessively contaminated soil will be left on-site, monitoring will be required until no further action criteria are achieved in affected media. If you have questions, please call me.

Engineering Review Comments; Remedial Action Plan for Site 103 at Truman Annex, NAS Key West; Gregory M. Brown, P.E.; October 26, 1994.

No.	*Page/Para*	*Comment*	*Response Required?*
1	General	Appendix B contains correspondence that documented decisions and data gaps to be addressed in the RAP. Specifically: 1) The RAP must present supporting data that all pathways for potential receptors of contamination have been eliminated; (2) The RAP must provide backup documentation to support the theory that the dock bulkhead is impermeable; and (3) The RAP should contain recommendations for soil and product removal in the vicinity of monitoring well MW-14. The RAP accomplishes item three satisfactorily, but none of the others. In addition, the specific requests made in the July 25, 1994 letter from J. Caspary (FDEP) to G. Magwood (SDIV) were not adequately addressed in the RAP. I recommend that the Navy include any risk evaluation summary presented in the CAR to support the lack of exposure pathways. The RAP could use the conclusions and recommendations of the risk evaluation as the basis of their remediation strategy. This would resolve some of the subsequent comments.	Yes
2	page 3-1/ para iii	"Exposure pathways through the soil media are limited; the latter two areas are not considered to contain contaminants of concern." The meaning of this statement is unclear. What exposure pathways? Are there no contaminants of concern because there are no exposure pathways or are there no exposure pathways because there are no contaminants of concern? Since by definition, the three areas shown in Figure 3-2 contain excessively contaminated soils as defined in FAC 62-770, the former condition must apply. Please request the Navy to make more explicit their rationale for this statement including their assumed exposure scenarios. (Answer to comment 1 may help resolve my confusion on this issue.)	Yes
3	Figures 3-3	I am not sure what figure 3-3 is trying to convey. The legend indicates that the shaded area to the west is ≤50 ppm. Is this a typo or does it mean that the unshaded areas are greater than 50 ppm (i.e. ≥50 ppm)?	Yes
4	page 3-6/para ii and iii	Tidal induced ground water fluctuations reduces the credibility of the "theory" that the bulkhead is hydraulically impermeable and is an effective barrier to contaminant migration. The Navy should report the magnitude and upland extent of the tidal influence and assess the extent of the hydraulic connection between ground water and surface water in a more quantitative manner. If enough data exist, a flow net analysis may be one of various methods adequate to accomplish it. Any persuasively presented analysis based on good scientific principles will be acceptable. Page 2-1, Section 2.2 reports that "There are existing underground utilities throughout the pier area..." Damaged and inadequately maintained storm drains through similar bulkheads at other Naval bases (e.g., NS Mayport, Alpha Delta pier) have acted as direct conduits to surface water for contaminated ground water. The Navy should adequately verify that they have considered and eliminated this potential release mechanism at Site 103, as well.	Yes
5	Table 4-1	Include Total Organic Halides	No
6	pg 4-1 / v	How are recovered water and LNAPL to be managed?	Yes
7	page 4-4	Excessively contaminated soil and contaminated ground water will remain after the removal of the LNAPL and associated soils. What is the monitoring plan?	Yes

ABB

January 6, 1995

Doc No. 07519-009

Mr. Eric Nuzie, Section-Chief
Bureau of Waste Cleanup
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, Florida 32399

SUBJECT: Submittal of the Response to Comments for the Remedial Action Plan for Site 103 at Truman Annex, Naval Air Station (NAS) Key West, Key West, Florida Contract No. N62467-89-D-0317, CTO No. 007.

Dear Eric:

Please find attached two copies of the Response to Comments for the Remedial Action Plan for Site 103 at the Truman Annex, NAS Key West, Key West, Florida. If you would please direct any concerns or discussion concerning these responses to either myself or Mike Dunaway at (904)-656-1293. Any written response should be addressed to Gabriel Magwood, Code 1849, Southern Division, Naval Facilities Engineering Command, 2155 Eagle Drive, North Charleston, SC, 29418, or he may be contacted by telephone at 803-743-0307.

Sincerely,

ABB Environmental Services, Inc.

Mark C. Diblin

Mark C. Diblin, P.G.
Task Order Manager

Enclosures

cc: Greg Brown (FDEP)
Gabriel Magwood (SouthDiv)
Bill Carlye (NAS Key West)
Mike Dunaway (ABB-ES)
Joe Ullo (ABB-ES)
File

ABB Environmental Services Inc.

2590 Executive Center Circle East
Berkeley Building
Tallahassee Florida 32301

Telephone (904) 656-1293
Fax (904) 877-0742

ABB An ABB Environmental Services, Inc.

Navy CLEAN

Underground Storage Tank Team

MEMORANDUM

DATE... 6 January 1995

TO: Greg Brown, P.E. II
Technical Review Section

INFO: Bill Carlye, NAS Key West

FROM: Mark Diblin, Mike Dunaway and Joe Ullo.

SUBJECT: Remedial Action Plan (RAP) Site 103, NAS Key West, Florida.

The comments received regarding the RAP for Site 103 at NAS Key West have been reviewed and addressed. Responses to the comments posed by Greg Brown, FDEP, on October 26, 1994 are listed below in order corresponding to the comment number shown on the issued memorandum attached (Attachment 1). Also attached are the correspondence submitted prior to the final RAP (Attachment 2) which includes the items which were to be addressed in the RAP as agreed upon by FDEP and ABB-ES. Site photographs, Attachment 3, are provided for a better understanding of the site, current activities and land use.

Comment 1 Response:

The three data gaps noted in comment one and the location of their associated responses are listed as follows:

1. The RAP must present supporting data that all pathways for potential receptors of contamination have been eliminated -- *Addressed in Response 2.*
2. The RAP must provide backup documentation to support the theory that the dock bulkhead is impermeable -- *Addressed in Response 4.*
3. The RAP should contain recommendations for soil and product removal in the vicinity of monitoring well MW-14 -- *Adequately addressed in the original RAP as noted in Comment 1.*

Following the transmittal of the memorandum which was written by Jorge Caspary, FDEP, on July 25, 1994, a second memorandum was sent to Jorge Caspary and FDEP by ABB-ES on July 27, 1994, regarding the justification proposal for using risk based procedures to develop alternative site rehabilitation levels (ASRL). To clarify final issues to be addressed in the RAP, a teleconference was held between Mark Diblin (ABB-ES) and Jorge Caspary (FDEP) on August 4, 1994. Documentation of this discussion is included in a telephone call memorandum written by Mark Diblin after the conversation. Items agreed upon in this discussion were the items of concern for the RAP. These documents are included as Attachment 2.

At FDEP's request no risk assessment was performed to set ASRL for the RAP. Although a risk assessment was not included in the contamination assessment (CA) phase, the Contamination Assessment Report Addendum did include evidence showing that the sea wall is inhibiting migration of groundwater contaminants into the turning basin as follows.

- No contamination was detected in the surface water sample collected along the seawall, which is directly downgradient of the total naphthalene plume.
- No contamination was detected in monitoring well MW-31D, which is located in the plume and is screened from 50 to 55 feet below land surface (bls). The bulkhead extends to a depth of 60 feet bls. Petroleum contamination migrating beneath the bulkhead into the turning basin would be detected in samples collected from MW-31D, if present.

Comment 2 Response:

As agreed in the August 4, 1994, telephone conversation, the only exposure scenario considered for soil contamination is for a construction worker installing shallow foundations or shallow buried utilities. Based on this scenario and the OVA data from ground level to 3 feet bls, there are no exposure pathways in the areas where free product is absent. The intent of the statement in question was that there were no contaminants of concern present in the soil included in the construction worker scenario. Contamination of surface soil is also below the FDEP guidance concentration for excessively contaminated soils with the exception noted in the RAP, section 3.1.1. Soil greater than 1 foot bls is not considered surface soil as defined by the USEPA, Region IV in their February 1, 1991 Standard Operating Procedures and Quality Assurance Manual. Figures 3-3 and 3-4 show that there is little surface soil contamination. On this basis it was agreed upon by FDEP, Southern Division, and ABB-ES that remedial actions in these areas were not necessary.

Comment 3 Response:

Figure 3-3 legend should show two areas of contamination with contamination levels $\geq$ 50 ppm and $\geq$ 10 ppm & $\leq$ 50 ppm. A corrected figure is shown in Attachment 4.

Comment 4 Response:

The hydraulic connection of the groundwater and the surface water is not in question. The original issue was the hydraulic permeability of the sea wall. This issue was addressed in the original RAP on page 3-6, paragraph iii. Copies of the papers referenced in the RAP are provided as Attachment 5.

Based on the low hydraulic conductivity of the sea wall, contaminant migration into the turning basin could only occur beneath the sea wall due to pressure head differentials, such as those caused by tidal fluctuations. Possible contaminant migration in this fashion should not pose problems in this case. Naphthalene is the only contaminant of concern which was detected in MW-20I. This well was used to characterize the vertical extent of contamination. Conservatively assuming a direct path beneath the sea wall into the turning basin from the screened interval of MW-20I, the contaminant transport velocity and the total time for transport were determined. These calculations combined with the degradation rate for naphthalene show the potential for migration beneath the bulkhead is negligible. These calculations are included in Attachment 6. Based on this calculation, naphthalene would not reach the surface water for close to 13 years, and the concentration of naphthalene in the groundwater at that time would have decreased to approximately .001 ppb which is well below the guidance concentration of 100 ppb.

Periodic inspections are performed on the sea wall by Navy personnel every 2 to 3 years. These inspections assure that appropriate actions would be taken if problems are encountered. It should also be noted that if the integrity of the sea wall were in question, the adverse effects (i.e. collapsing of the sea wall and the structures associated with it, and the possible rupture of utility lines within the sea wall area) would go well beyond the issue of contaminant transport assuring that immediate response actions would be taken.

Unlike other bases such as NAS Mayport, there is little reason to suspect that contaminant transport into the turning basin is being assisted by inadequately maintained storm drains. There have been no reported problems or leaks due to storm drains at Truman Annex. The groundwater elevation contour maps do not show flow trends which would indicate draining through the existing storm sewer network as was the case at the Alpha Delta pier, NAS Mayport. Contaminant migration appears to be independent of the subsurface utilities based on plume configurations and known groundwater flow directions. The surface water sample taken along the seawall was directly downgradient of the total naphthalene and TRPH plume. This sample was also taken in the immediate vicinity of a stormwater drain near Building 102 which runs through the contaminant plume. No contamination was detected in this sample. If more verification of the integrity of the storm drain or other utilities is necessary, further clarification of FDEP's concerns would be required.

Comment 5 Response:

Not required.

Comment 6 Response:

It has been agreed upon that groundwater remediation at this site is not necessary, however, groundwater associated with free product should be addressed. On page 4-4 of the RAP free product removal is addressed. Only incidental groundwater will be removed if necessary during free product recovery. A tanker-truck with vacuum connections is recommended or some other equivalent recovery method chosen by the Remedial Action Contract (RAC) contractor.

Comment 7 Response:

It was agreed that the groundwater would not be of concern in the RAP if proof of negligible migration and exposure pathways were shown. There are no potable wells in the site vicinity. The potable water supply for the key is obtained from the mainland via the Florida Aqueduct. Documentation supporting negligible migration of the groundwater has been provided as requested by FDEP in the memorandum on August 4, 1994. In addition, the CARA shows decreasing groundwater contaminant levels in many of the monitoring wells between the sampling events in August 1991 and March 1993.

Primary soil exposure pathways will be eliminated by the remedial actions in the immediate area of monitoring well MW-14. As stated in the response to comment 2 and shown in the RAP, there is little surface soil contamination outside of this area. For these reasons, continued monitoring of the soil and groundwater is not considered necessary and no further action is recommended.

ATTACHMENT 1

Remedial Action Plan
Site 103, NAS Key West, Florida
Response to Comments

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

November 14, 1994

Mr. Gabriel Magwood, Code 1849
Southern Division
Naval Facilities Engineering Command
PO Box 190010
North Charleston, S.C. 29419-9010

RE: Remedial Action Plan for Site 103.
Naval Air Station Key West

Dear Mr. Magwood:

The Department has reviewed the Draft Remedial Action Plan for Site 103, dated August 1994 (received October 18, 1994). Enclosed are comments from Greg Brown on the report. The comments must be adequately addressed in an addendum to the RAP.

In case of any assistance in this matter, please contact me or Greg Brown at 904/488-3935.

Sincerely,

Jorge R. Caspary, P.G.
Remedial Project Manager

Enclosures

cc: Michael K. Dunaway, ABB-Tallahassee
Bill Carlye, NAS Key West
Mark Diblin, ABB-Tallahassee

TJB ___ JJC ___ ESN ESN

Florida Department of
Environmental Protection

Memorandum

TO: Jorge Caspary, P.G., Remedial Project Manager, Technical Review Section

THROUGH: Tim Bahr, P.G., Supervisor, Technical Review Section TB

FROM: Greg Brown, P.E. II, Technical Review Section GB

DATE: October 26, 1994

SUBJECT: Remedial Action Plan for Site 103 at Truman Annex for Naval Air Station, Key West, Florida, August 1994.

I have reviewed the subject document and my specific comments are attached. I recommend that the Navy proceed with the limited soil and free product removal described in the RAP as an interim remedial action. Other important issues remain outstanding, however. The Navy must adequately address them before the RAP can be approved. These include:

- provide sufficient justification that all pathways to potential receptors under likely exposure scenarios have been eliminated;
- provide adequate evidence that the bulkhead is impermeable; and
- prepare and implement a monitoring plan.

The limited remedial action proposed in the RAP may be justified if a better effort is made in the document to show that weak exposure pathways exist under likely exposure scenarios. The impermeability of the bulkhead is also a critical issue since there may be a direct link between contaminated ground water and receiving surface water bodies. Because contaminated ground water and excessively contaminated soil will be left on-site, monitoring will be required until no further action criteria are achieved in affected media. If you have questions, please call me.

Engineering Review Comments; Remedial Action Plan for Site 103 at Truman Annex, NAS Key West; Gregory M. Brown, P.E.; October 26, 1994.

No.	*Page/Para*	*Comment*	*Response Required?*
1	General	Appendix B contains correspondence that documented decisions and data gaps to be addressed in the RAP. Specifically: 1) The RAP must present supporting data that all pathways for potential receptors of contamination have been eliminated; (2) The RAP must provide backup documentation to support the theory that the dock bulkhead is impermeable; and (3) The RAP should contain recommendations for soil and product removal in the vicinity of monitoring well MW-14. The RAP accomplishes item three satisfactorily, but none of the others. In addition, the specific requests made in the July 25, 1994 letter from J. Caspary (FDEP) to G. Magwood (SDIV) were not adequately addressed in the RAP. I recommend that the Navy include any risk evaluation summary presented in the CAR to support the lack of exposure pathways. The RAP could use the conclusions and recommendations of the risk evaluation as the basis of their remediation strategy. This would resolve some of the subsequent comments.	Yes
2	page 3-1/ para iii	"Exposure pathways through the soil media are limited; the latter two areas are not considered to contain contaminants of concern." The meaning of this statement is unclear. What exposure pathways? Are there no contaminants of concern because there are no exposure pathways or are there no exposure pathways because there are no contaminants of concern? Since by definition, the three areas shown in Figure 3-2 contain excessively contaminated soils as defined in FAC 62-770, the former condition must apply. Please request the Navy to make more explicit their rationale for this statement including their assumed exposure scenarios. (Answer to comment 1 may help resolve my confusion on this issue.)	Yes
3	Figures 3-3	I am not sure what figure 3-3 is trying to convey. The legend indicates that the shaded area to the west is ≤50 ppm. Is this a typo or does it mean that the unshaded areas are greater than 50 ppm (i.e. ≥50 ppm)?	Yes
4	page 3-6/para ii and iii	Tidal induced ground water fluctuations reduces the credibility of the "theory" that the bulkhead is hydraulically impermeable and is an effective barrier to contaminant migration. The Navy should report the magnitude and upland extent of the tidal influence and assess the extent of the hydraulic connection between ground water and surface water in a more quantitative manner. If enough data exist, a flow net analysis may be one of various methods adequate to accomplish it. Any persuasively presented analysis based on good scientific principles will be acceptable. Page 2-1, Section 2.2 reports that "There are existing underground utilities throughout the pier area..." Damaged and inadequately maintained storm drains through similar bulkheads at other Naval bases (e.g., NS Mayport, Alpha Delta pier) have acted as direct conduits to surface water for contaminated ground water. The Navy should adequately verify that they have considered and eliminated this potential release mechanism at Site 103, as well.	Yes
5	Table 4-1	Include Total Organic Halides	No
6	pg 4-1 / v	How are recovered water and LNAPL to be managed?	Yes
7	page 4-4	Excessively contaminated soil and contaminated ground water will remain after the removal of the LNAPL and associated soils. What is the monitoring plan?	Yes

ATTACHMENT 2

Remedial Action Plan
Site 103, NAS Key West, Florida
Response to Comments

Department of
Environmental Protection

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Lawton Chiles
Governor

Virginia B. Wetherell
Secretary

rec'd Aug. 1, 1994
MCD

July 25, 1994

Mr. Gabriel Magwood
Petroleum Branch
SOUTHNAVFACENGCOM
2155 Eagle Dr., P.O. Box 190010
North Charleston, S.C. 28419-9010

Subject: RAP/Risk Assessment at Site 103. Naval Air Station Key West.

Dear Mr. Magwood:

This letter will serve to confirm the telephone conversation sustained with you and ABB-ES outlining the course of action for the above referenced site.

After consulting with Ms. Ligia Mora-Applegate, the Department's toxicoloist, the following steps regarding this site are listed in order to comply with RUle 17-770 F.A.C.:

1. The Department shall receive, in writing, a request to conduct a Risk Evaluation/Assessment for this site. All pertinent information such as formulas and assumptions to be used should be included to justify this step.

2. As part of the Risk Evaluation, the Navy shall commit to conduct an engineering evaluation of the seawall and appurtenances for permeability and associated geotechnical properties. The evaluation shall be signed and sealed by a Registered Engineer competent in the area. Likewise, the Navy shall commit to an Departmental-agreed periodic inspection/evaluation of the seawall for integrity. The inspection program shall be continued until the levels of constituents in all pertinent monitoring wells are in compliance with Rule 17-302 F.A.C.

3. The Department feels that there is no need to conduct a risk evaluation for soils; therefore, the only step regarding this media is the agreed-before removal of soils around the above ground storage tank.

4. According to Ms. Mora-Applegate, US EPA Risk Assessment Guidelines (RAGS) Part B have changed. It is therefore necessary the ABB-ES toxicologist be aware of these changes.

If I can be of any assistance in this matter please contact me at 904/488-3935.

Sincerely,

Jorge R. Caspary

Jorge R. Caspary, P.G.
Federal Facilities Group

cc: Jorge R. Caspary
Bill Hunt, NAS Key West
Mark Diblin, ABB Tallahassee

ABB

07519-002

27 July, 1994

Mr. Jorge Caspary
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, Florida 32301

SUBJECT: **Justification Proposal For Using Risk Based Procedures to Develop Alternative Site Rehabilitation Levels**
Electric Power Plant (Building 103)
Truman Annex, Naval Air Station,
Key West, Florida

Dear Jorge:

In accordance with the requirements of Florida Administrative Code (FAC) Chapter 17-770.630(5)(a), ABB Environmental Services, Inc. (ABB-ES) herein proposes the development of Alternative Site Rehabilitation Levels (ASRL's) for groundwater at Building 103, NAS Key West, based on acceptable risk levels. The proposed methodologies for developing the ASRL's are attached. The resulting ASRL's will be presented in the Remedial Action Plan (RAP) for the site along with an evaluation of the ability of the existing bulkhead to prevent groundwater contamination from migrating into the turning basin. The RAP will also present any additional proposed remedial actions.

Any questions regarding this proposal should be directed to me or Mike Dunaway at (904) 656-1293.

Sincerely,

Mark Diblin

Mark Diblin, P.G.
Task Order Manager

Mike Dunaway, P.E.
Principal Engineer

cc: Gabriel Magwood (SouthDiv)
Bill Hunt (NAS Key West)
Marland Dulaney (ABB-ES)
Mike Dunaway (ABB-ES)
Eric Nuzie (FDEP)
file 07519-50

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ABB Environmental Services Inc.

2590 Executive Center Circle East
Berkeley Building
Tallahassee, Florida 32301

Telephone (904) 656-1293
Fax (904) 877-0742

Attachment 11 (C)

2. Groundwater (Non-potable Residential Use):

- Following USGS information, groundwater not considered potable water source. Only non-potable water uses considered.
- Non-potable water used in residential setting for washing of outdoor items and irrigation.
- Non-potable exposure consists of dermal contact and absorption of all contaminants detected in groundwater. Contaminants detected in soil are assumed to migrate into groundwater.
- Non-potable groundwater exposure assumed to occur 1 hour per day, 350 days/year, for 30 years.
- Standard Risk Assessment Guidance for Superfund Part B exposure equations used to establish ASRLs.
- Technical approach and exposure equations similar to those used for RCRA site at Hangar 1000, NAS Jacksonville, Jacksonville, FL, which was accepted by FDEP risk assessment reviewers.

Carcinogenic Effects (Water):

$$C_{water} = \frac{TR \times BW \times AT \times 365\, days/year}{EF \times ED \times ET \times [SF_d] \times PC \times 10^{-6} \times SA}$$

where:

C_{water}	Target Chemical Water Concentration (µg/L)
TR	Target Excess Individual Lifetime Cancer Risk (unitless)
BW	Body Weight (kg)
AT	Averaging Time (yr)
EF	Exposure Frequency (days/yr)
ED	Exposure Duration (yr)
ET	Exposure Time (hr/day)
SF_D	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$
CF	Conversion Factor (10^{-6} kg/mg)
SA	Exposed Skin Surface Area (cm^2)
PC	Chemical Specific Dermal Permeability Constant (cm/hr)

Attachment II (con

Non-carcinogenic Effects (Water)

$$C_{water} = \frac{THI \times BW \times AT \times 365\,days/year}{EF \times ED \times ET \times [\frac{1}{RfD_d}] \times PC \times 10^{-6} \times SA}$$

where:

C_{water}	Target Chemical Water Concentration (μg/L)
THI	Target Hazard Index (unitless)
BW	Body Weight (kg)
AT	Averaging Time (yr)
EF	Exposure Frequency (days/yr)
ED	Exposure Duration (yr)
ET	Exposure Time (hr/day)
RfD_d	Dermal Reference Dose (mg/kg-day)
CF	Conversion Factor (10^{-6} kg/mg)
SA	Exposed Skin Surface Area (cm^2)
PC	Chemical Specific Dermal Permeability Constant (cm/hr)

ATTACHMENT 3

Remedial Action Plan
Site 103, NAS Key West, Florida
Response to Comments

An ABB Environmental Services, Inc.

Telephone Call MEMORANDUM

ASEA BROWN BOVERI

DATE: 4 August 1994

INCOMING: _X_ **OUTGOING:** ___

PROJECT: NAS Key West, Site 103

SUBJECT: Items for consideration for present Remedial Action Plan

PARTICIPANTS: Mark Diblin, ABB-ES and Jorge Caspary, FDEP MCD

DISCUSSIONS:

These items are agreed to be the items of concern for the Remedial Action Plan at Site 103. These items are the result of the prior meeting between ABB-ES, FDEP, and SOUTHDIV on 1 July 1994.

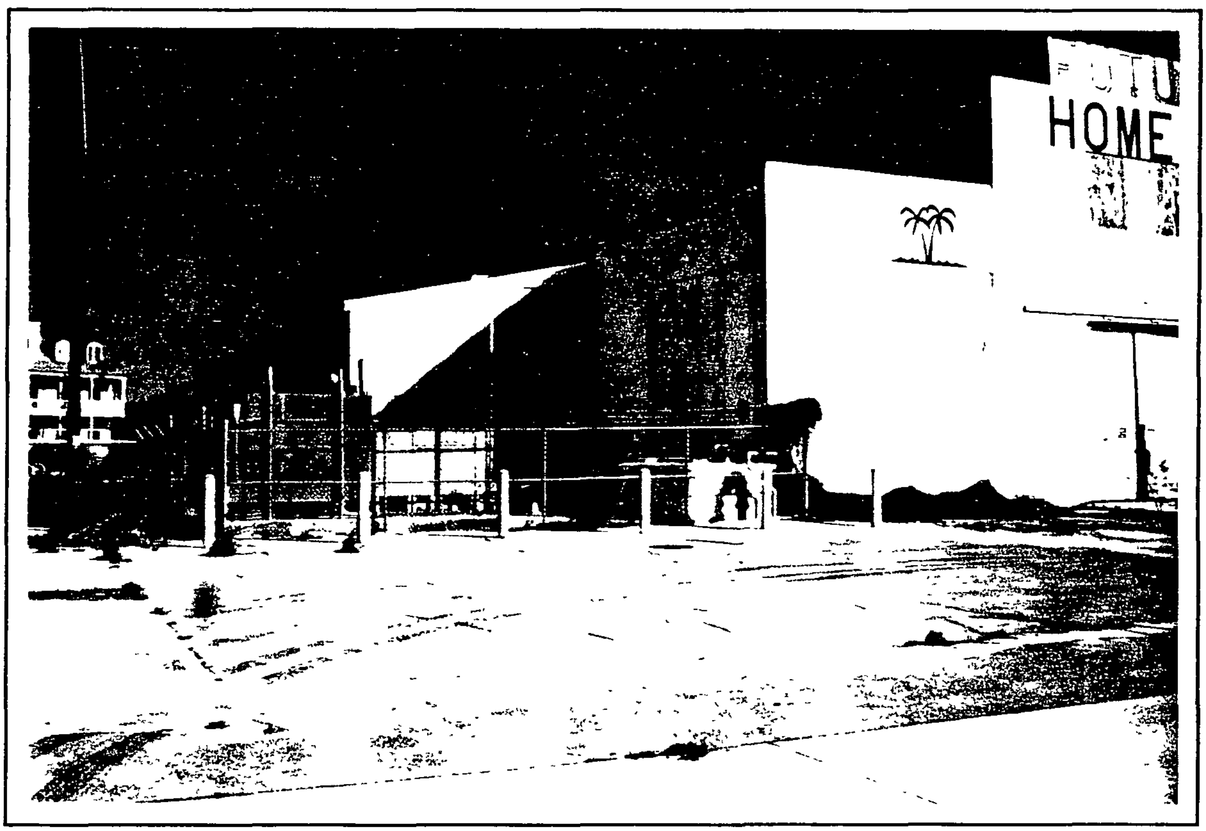
1. Soil Contamination:
   a. The RAP must demonstrate no exposure pathway and no risk of contamination to the average construction worker.
   b. The RAP must address source abatement, i.e. disposal of contaminated soil saturated with free product in the vicinity of monitoring well MW-14

2. Groundwater Contamination:
   a. The RAP must assure that the groundwater is not being used as potable water, i.e. there are no potable wells in Key West.
   b. The RAP should provide documentation to support negligible migration of the groundwater and thereby allow for a no further action criteria.
   c. With respect to the bulkhead:
      i. The RAP should show that the bulkhead is impermeable.
      ii. The RAP should include an inspection and monitoring schedule for the bulkhead. The schedule should be set based on technical information concerning the bulkhead design and the bulkhead specifications for integrity over a given period of time.
      iii. Technical reasons justifying the low permeability of the sea wall should be included.

DISTRIBUTION:

G. Magwood, Southern Division
M. Dunaway, ABB-ES
J. Caspary, FDEP
M. Dulaney, ABB-ES
J. Ullo, ABB-ES
File

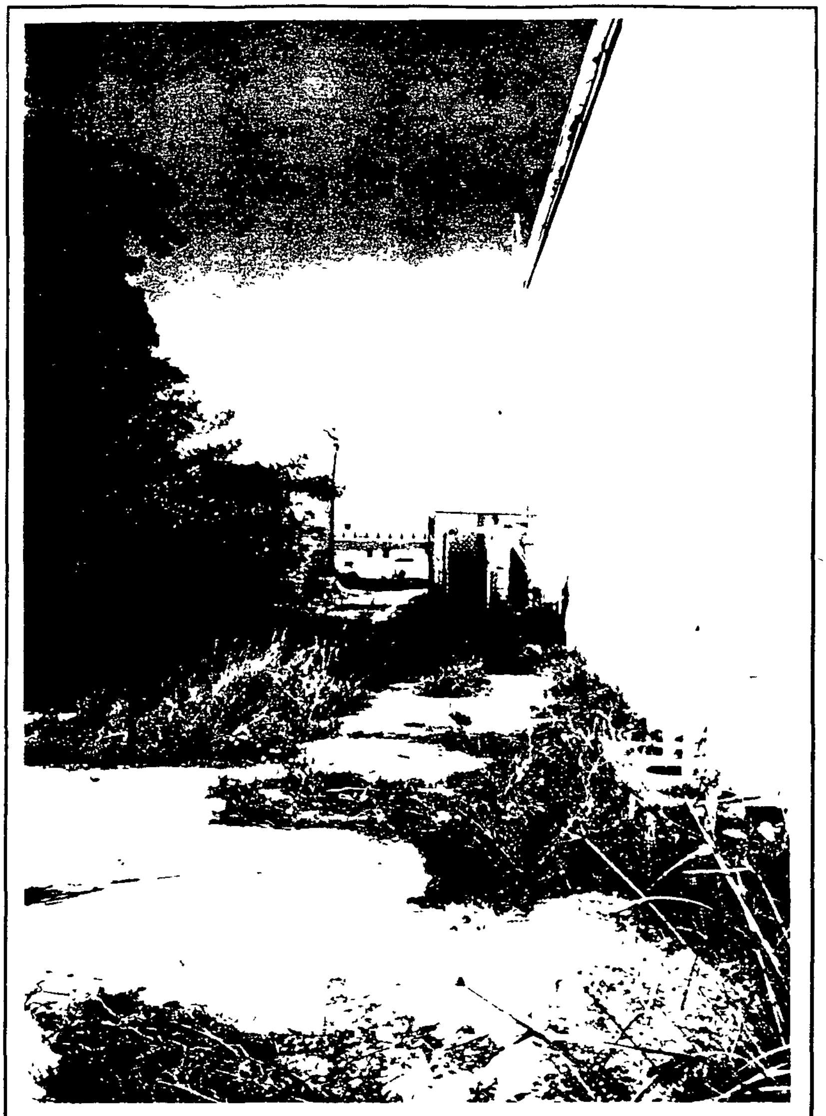
Photograph No. 1: Looking Northeast
Building 103, Former Electric Power Plant



Photograph No. 2: Looking Southeast
Northwest corner of Building 102. Inactive pumping control area. Also shown is the new condominium on the adjacent property.

Photograph No. 3: Looking West
Back of Building 103 (left) and Building 102 (right).

Photograph No. 4: Looking West-Northwest
Back of Building 102 (left) and side of Building 159 (center). Residential housing on the adjacent property (right).

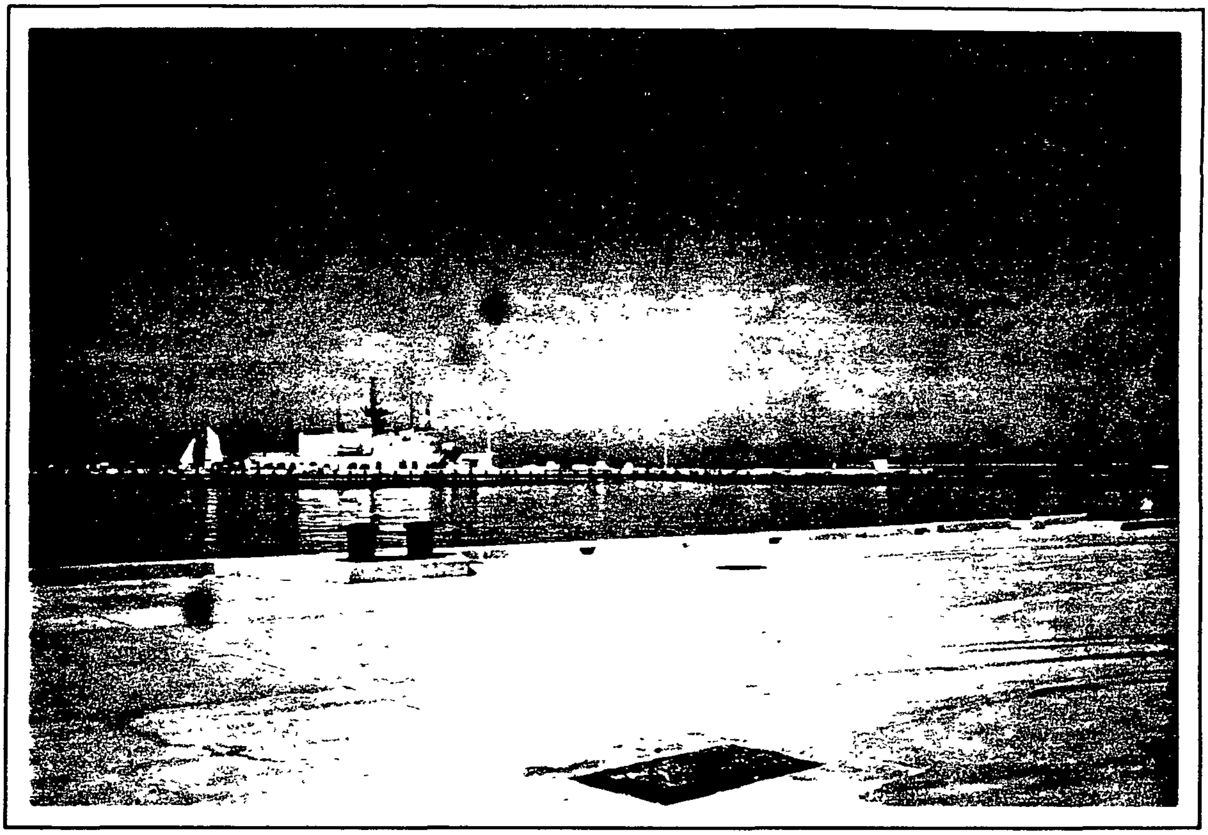


Photograph No. 5:
Looking West

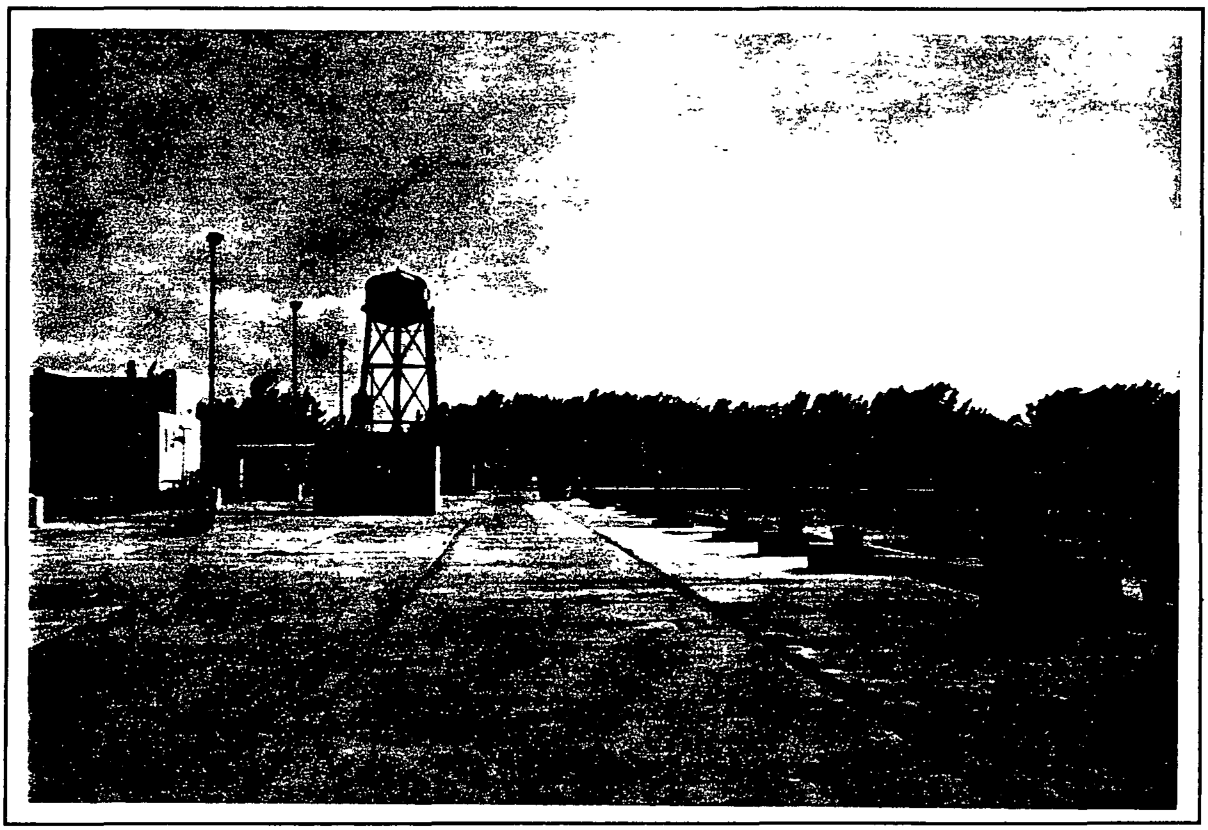
Area between Building 103 (left) and Building 102 (right).

Photograph No. 6 (below):
Looking East

Area between Building 103 (left) and Building 104 (right). Proposed excavation area is visible in the distance.



Photograph No. 7: Looking West
The new concrete wharf and turning basin as they appear just north of Building 103. New tie downs (left) are shown.



Photograph No. 8: Looking South
The new concrete wharf. Building 103 is also shown as well as new service boxes (far right).

ATTACHMENT 4

Remedial Action Plan
Site 103, NAS Key West, Florida
Response to Comments

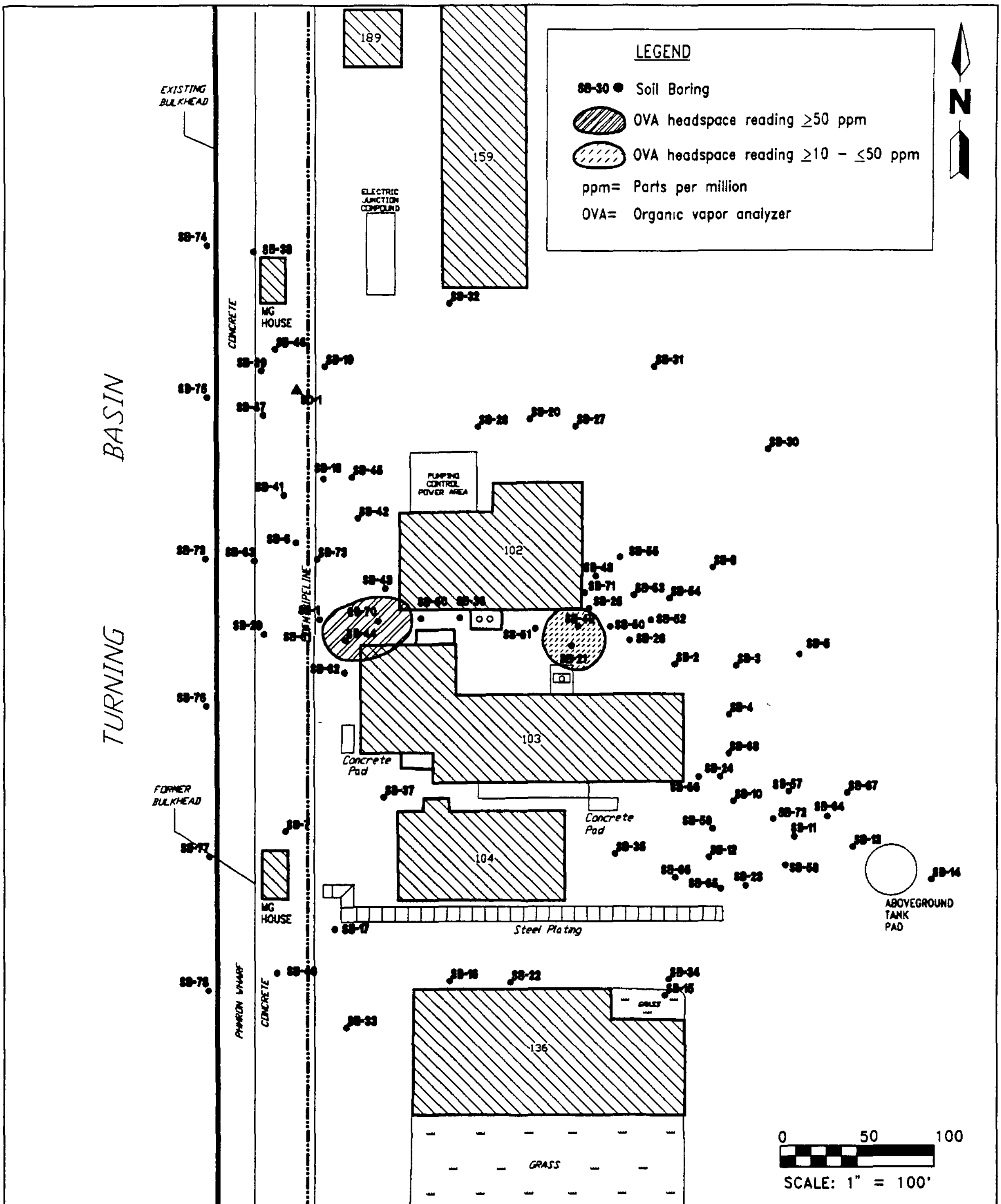


FIGURE 3-3
SOIL CONTAMINATION DISTRIBUTION, 0 TO 1 FOOT BELOW LAND SURFACE

KEYWEST\BLDG-103\WDW-CCK\08-24-94

SOUTHERN DIVISION NAVAL FACILITIES ENGINEERING COMMAND

REMEDIAL ACTION PLAN
BUILDING 103

TRUMAN ANNEX
NAVAL AIR STATION
KEY WEST, FLORIDA

ATTACHMENT 5

Remedial Action Plan
Site 103, NAS Key West, Florida
Response to Comments

Applications of Low Permeability Cutoff Walls for Groundwater Pollution Control

Robert C. Starr and John A. Cherry
Waterloo Centre for Groundwater Research
University of Waterloo, Waterloo, ON

SYNOPSIS

Low hydraulic conductivity cutoff walls are increasingly being used in groundwater pollution control and remediation applications. Conventional and recently developed configurations of barrier walls are described. The new configurations can completely prevent advection of contaminated groundwater through cutoff walls. Cutoff walls can be advantageously used in conjunction with other groundwater remediation methods for controlling migration of contamination in the subsurface, and for renovating contaminated zones. This paper considers the role of conventional cutoff walls such as soil-bentonite slurry walls in groundwater pollution control as well as new types of walls such as plastic membrane walls, sealable-joint sheet piling walls, and jet grouted walls.

INTRODUCTION

Groundwater contamination of urban, commercial, industrial, and agricultural areas is becoming an increasingly common occurrence. In a typical groundwater contamination situation, a dissolved plume of contaminated groundwater emanates from a source zone that contains soluble solids, liquids, or gases, high concentrations of sorbed contaminants, or a large mass of solutes that has diffused into the low hydraulic conductivity portion of a dual porosity medium. The usual goals of site remediation efforts include preventing contaminants from migrating off site, reaching groundwater discharge zones, or crossing some arbitrary boundary such as a property line. Site control activities typically include preventing plume migration by hydraulic means, including extraction wells and low hydraulic conductivity barriers, removing the dissolved plume, and removing or isolating the source. Plume and source removal are usually accomplished by pump-and-treat systems or some other physical, chemical, or biological in situ remediation technique. The effectiveness of pump-and-treat systems for affecting permanent remediation of sites is questionable (Mackay and Cherry, 1989), so there is an increasing interest in source isolation and in situ remediation as a means of dealing with contaminated sites.

This paper discusses the use of low hydraulic conductivity cutoff walls in groundwater pollution control programs. Cutoff walls can be used with or without extraction wells, and can also be used to enhance the effectiveness of in situ remediation techniques.

CUTOFF WALL CONSTRUCTION METHODS

A variety of cutoff wall construction methods are described by Starr and Cherry (1990). Common cutoff wall techniques include slurry trench methods (soil bentonite, soil attapulgite, and cement bentonite), grouting methods (jet grouting and vibrated beam), caisson / auger cast piles, high density polyethylene walls, and conventional and sealable joint sheet piling. Given the variety of techniques available, it is unlikely that one method would be the optimum choice for all situations.

The choice of a wall construction technique should be based on technical and economic considerations. Technical considerations include the feasibility of constructing a wall of a given type, the expected performance as a barrier to contaminant migration, durability, and the effects of construction on nearby facilities. Additional important factors include the ease with which relevant construction inspection activities can be performed, if post construction performance tests can be conducted, and the ease with which imperfections can be identified and repaired. Economic factors include costs for site characterization, engineering design, construction inspection, mobilization and setup, construction of ancillary infrastructure, the unit cost of construction, construction inspection and testing, disposal of waste materials including contaminated soil generated as spoil or cuttings, disruption to normal site activities, and damage to existing facilities.

EFFECT OF WALL PROPERTIES AND IMPERFECTIONS ON FLOW THROUGH THE WALL

The usual goal of constructing a low hydraulic conductivity cutoff wall is to reduce the flux of groundwater through the wall, and thereby the flux of contaminants. The flux of groundwater through a cutoff wall is proportional to the difference in hydraulic head across the wall and the ratio of wall hydraulic conductivity to thickness. The flux of contaminants through a wall can be minimized by decreasing the hydraulic head difference across the wall, or prevented altogether by having the hydraulic head on the contaminated side of the wall less than that on the uncontaminated side of the wall. Decreasing the hydraulic conductivity of the wall and increasing the thickness of the wall also decreases the flux of contaminants through the wall.

Cutoff walls generally consist mainly of low hydraulic conductivity material, but often also contain imperfections that have higher hydraulic conductivity. These imperfections cause the overall hydraulic conductivity of the cutoff wall to be greater than it would be if the imperfections were not present. Starr et al. (1992) discuss the effect of imperfections on the hydraulic conductivity of the cutoff wall as a whole. Therefore, construction methods that are not prone to having imperfections, and that are amenable to inspection and testing procedures that prevent or at least detect imperfections, are preferred over construction methods that are prone to imperfections or are difficult to inspect. For example, slurry trench methods offer many possibilities for confirming that the wall extends to the intended depth and that the geologic material at the bottom of the excavation is the expected material, that the low hydraulic conductivity backfill has the desired characteristics before it is placed into the trench, and that there are no lenses or layers of high hydraulic conductivity soil atop the backfill slope or at the bottom of the trench. Sealable joint sheet piling (Starr et. al. 1992) is also amenable to meaningful construction inspection. In contrast, in our experience grouting techniques are much less amenable to relevant inspection during construction. Although it is straightforward to determine the characteristics of the material being injected into the ground and the location of the top of the borehole, it is extremely difficult to confirm where the material actually goes in the subsurface and hence to be confident that a continuous low hydraulic conductivity barrier has been constructed.

A second aspect of quality control is that most configurations of cutoff walls are not well suited to post-construction hydraulic tests that indicate the as-built hydraulic integrity. Configurations that are well suited to meaningful tests are described in a subsequent section. Our bias in selecting wall construction methods and configurations is in favour of methods that are not prone to having imperfections and that can be subjected to meaningful inspection during construction, and to configurations that are well suited for performance testing after construction.

EFFECT OF CUTOFF WALL CONFIGURATION ON GROUNDWATER FLOW

The effect of various shapes of cutoff walls on groundwater flow systems and hence contaminant transport was investigated by mathematical modelling. The model used, FLOWPATH (Waterloo Hydrogeologic Software, Waterloo, Ontario), is a 2D plan view, steady state flow model with particle tracking. Particles represent a body of contaminant, and a pathline is the path followed by the centre of mass of the contaminant body. The simulated system is an unconfined sandy aquifer with an isotropic hydraulic conductivity of 10^{-3} cm/s, and a porosity of 0.2. The net infiltration is 25 cm/a. The cutoff walls are oriented perpendicular to the regional flow direction, are one metre thick, and have a hydraulic conductivity of 10^{-6} cm/s and porosity of 0.2. The arrows shown in the figures are velocity vectors.

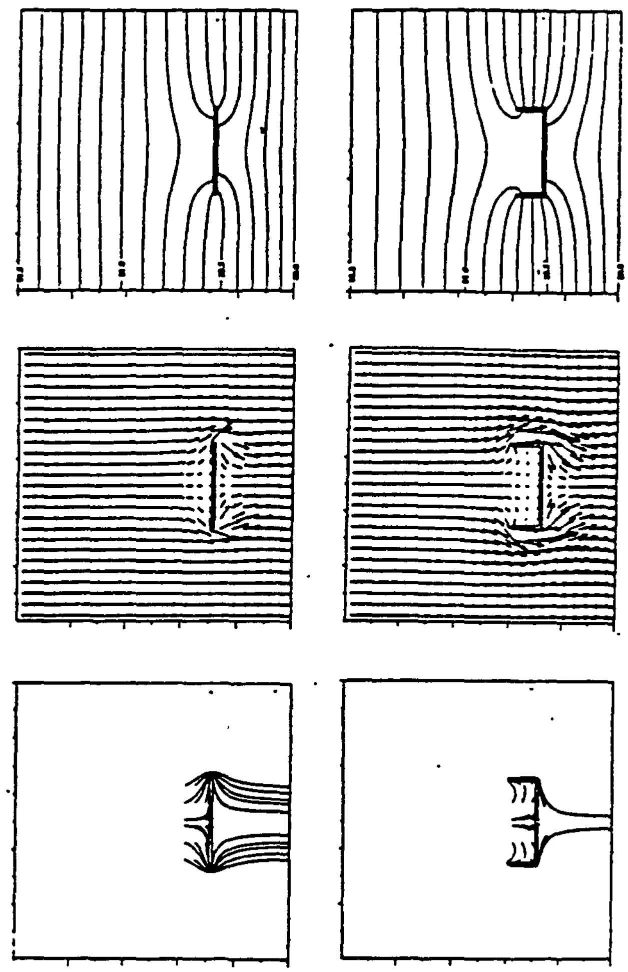


Figure 1: Left: straight cutoff wall; Right: cutoff wall with upstream extensions; Top: hydraulic head; Middle: groundwater velocity; Bottom: particle pathlines.

Figure 1 (left) shows the case of a straight linear wall. Three features that are typical of cutoff wall systems can be observed. First, the wall induces mounding of the water table on the upgradient (left) side of the wall, and the hydraulic head is greater on the left side of the wall than on the right side. Second, the wall causes groundwater to be deflected around the ends of the wall. The velocity near the ends of the wall is greater than it is the remainder of the flow field, and is greater than it would be if the wall were not present. Third, the wall is not a perfect barrier to contaminant transport. Some particles are swept around the ends of the wall, but some remain upstream of the wall for 1000 days. At longer times, some particles pass through the wall and all reach the exit boundary. If the wall was not present, all particles would reach the right hand boundary of the domain within 1000 days so the wall clearly slows the migration of some contaminant mass. As was discussed in a previous section, the flux of water through a wall is proportional to the hydraulic conductivity of the wall. The hydraulic conductivity of a cutoff wall cannot be reduced to zero, so the flux of water through a wall cannot be reduced to zero unless the hydraulic head difference across the wall is also reduced to zero. Hence, it is to be expected that some contaminant mass and therefore pathlines pass through the wall.

Although a common perception of the effect of cutoff walls is that they prevent groundwater flow, a more accurate description is that cutoff walls disrupt groundwater flow patterns. The goal in selecting a cutoff wall configuration and location relative to the contaminant source is to utilize the changes in the flow field to maximum advantage. For example, the velocity plot shows that low velocity zones are located immediately upstream and downstream of the wall.

Contaminants located in either area have a slower transport velocity than they would if the wall was not present. However, both low velocity zones are small. A possible way of increasing the size of the low velocity zone and improving the effectiveness of the wall as a contaminant transport barrier is to have cutoff wall segments parallel to the regional flow direction, either upstream or downstream of the main portion of the wall.

The effect of having extensions of the cutoff wall that project ten metres upstream is illustrated in Figure 1 (right). There is again mounding of the water table on the upstream side of the wall and a depression on the downstream side, low velocity zones upstream and downstream of the centre portion of the wall, and high velocity zones near the ends of the wall. However, the low velocity zone on the upstream side of the wall is larger than in the case for the straight wall without extensions. Eddies are formed near the ends of the upstream extensions of the walls, and there is a component of flow upstream relative to the overall flow direction and around the ends of the wall.

The pathlines followed by particles released upstream of the wall during 1000 days are also shown. Particles released near the upstream ends of the extensions are swept around the ends of the wall by the eddies, and rapidly transported far downstream of the wall. However, particles released into the middle of the space surrounded by the wall and extensions remain inside the space during the 1000 day simulation period, but at longer simulation times all particles reach the right hand boundary of the domain. Use of extensions upstream of the main portion of the cutoff wall increases the effectiveness of the cutoff wall as a barrier to contaminant migration by increasing the size of the low velocity zone upstream of the wall.

A cutoff wall with extensions downstream of the main portion of the wall is shown on Figure 2 (left). The low velocity zone on the downstream side of the wall, in the area partially enclosed by the extensions, is larger than the low velocity zone downstream of the cutoff wall without extensions. Velocities in this zone are not zero because there is a flux of water through the walls, recharge to the aquifer, and water flowing around the ends of the extensions. Figure 2 shows the pathlines taken by particles during 1000 days. Although some particles travel a shorter distance than they

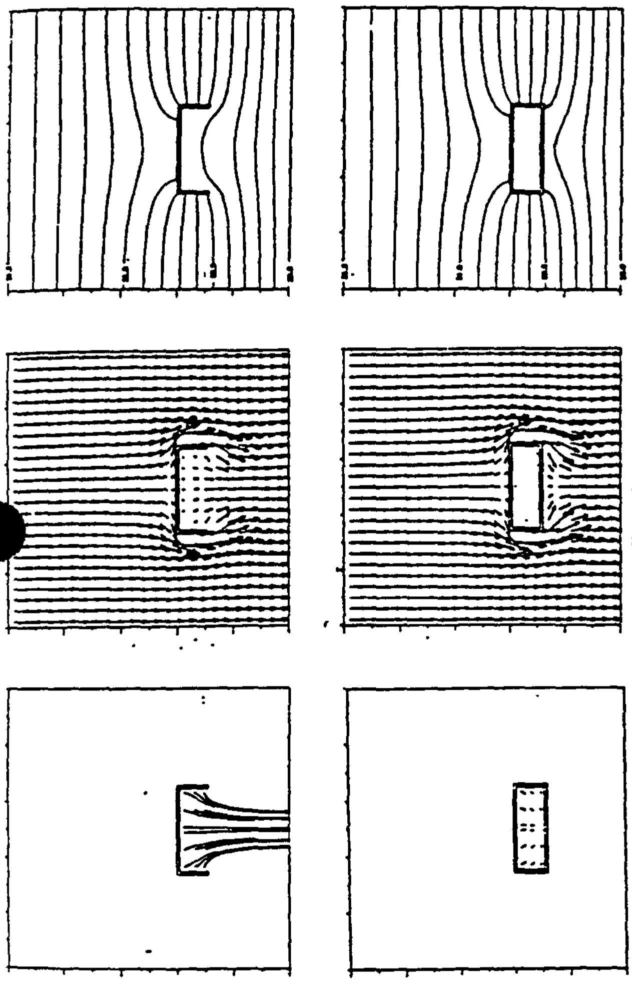


Figure 2: Left: cutoff wall with downstream extensions; Right: cutoff wall enclosure.

would if there was no wall, most of the particles reach the exit boundary during the simulation period. Therefore, this configuration of wall does not appear to be an effective barrier to contaminant transport.

A cutoff wall cell that totally surrounds a portion of the aquifer is shown in Figure 2 (right). Inside the cell, velocities are much smaller than in any of the cases illustrated previously. This suggests that this configuration is more effective at preventing contaminant migration than the other configurations illustrated. However, there is a hydraulic gradient across the cell walls, and hence a flux of groundwater into and out of the cell, and recharge into the cell interior. Hence, the cell is not a complete barrier to migration. All particles eventually reach the exit boundary, as is the case for all other configurations shown. Figure 2 (right) shows pathlines after 1000 days of travel. Travel distances in this case are much less than those in comparable figures shown earlier, indicating that the cellular configuration is a more effective barrier to contaminant migration than the configurations illustrated previously.

The effect of extraction wells in addition to cutoff walls is illustrated in the next suite of figures. Figure 3 (left) shows an extraction well located upstream of cutoff wall without upstream or downstream extensions. A pumping rate of 8 m^3/d is sufficient to capture all of the particles during a 1000 day simulation period, although particles reach the exit boundary of longer times. Pumping at this rate prevents groundwater and particles from migrating around the ends of the wall, and therefore improves the performance of the cutoff wall. However, if the wall was not present an extraction rate of 8 m^3/d would not be sufficient to capture all of the particles. Therefore, the cutoff wall improves the efficiency of the pump-and-treat system. In addition, the wall provides a safety factor if the extraction well fails because contaminants do not rapidly move downstream of the capture zone of the well as they would if no wall was present.

A wall with upstream extensions and an extraction well on the upstream side is shown in Figure 3 (right). A well pumping at 4 m^3/d captures all of the particles during a 1000 day simulation efficiency of the extraction well more than a wall without upstream extensions. This wall configuration provides a greater safety factor if the well fails than the wall without extensions.

A wall with downstream extensions and an extraction well downstream of the wall is shown on Figure 4 (left). A well pumping at only 1 m^3/d captures all of the particles. The extraction well improves the effectiveness of the well as a contaminant migration barrier, and the wall improves the efficiency of the wall by reducing the volume of water that must be pumped. The disadvantage of this configuration is that if the extraction well fails, contaminants rapidly migrate downstream of the capture zone of the well.

An encircling wall with an extraction well pumping at 1 m^3/d is sufficient to keep the hydraulic head in the interior below that outside (Figure 4 (right)). All of the particles are captured by the extraction well. One advantage of this configuration over non-encircling walls is that if the extraction well fails, contaminant migration out of the enclosure is much slower than in the other configurations.

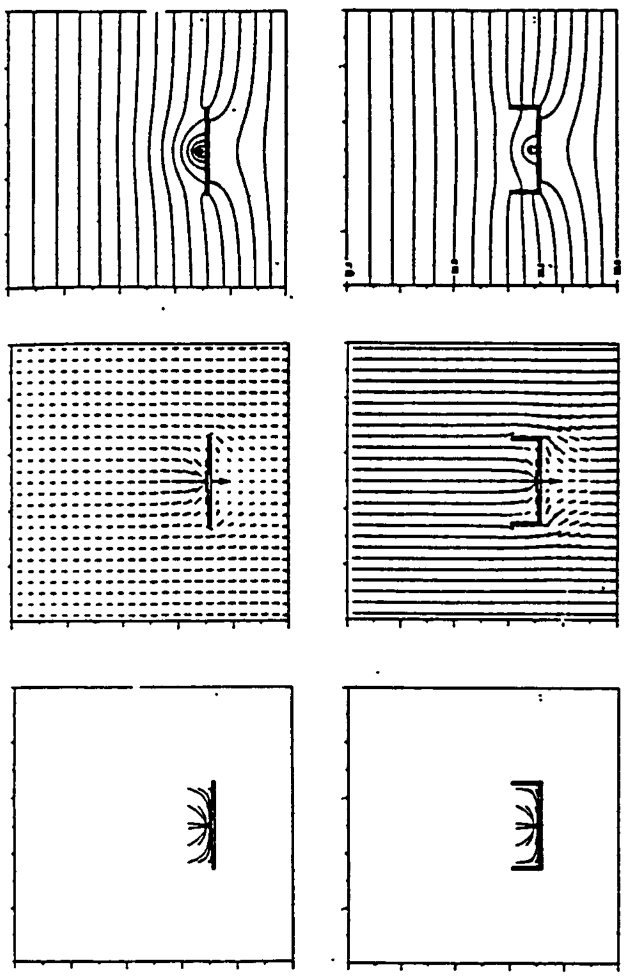


Figure 3: Left: straight cutoff wall with extraction well; Right: cutoff well with upstream extensions and extraction well.

period, although some reach the exit boundary at steady state. The extraction well improves the performance of the cutoff wall, and this configuration of cutoff wall improves the

NON-CONVENTIONAL WALL CONFIGURATIONS AND APPLICATIONS

Cutoff walls are typically open ended structures, not enclosures. However, enclosures provide better containment than open ended walls, particularly if hydraulic control inside the enclosure is maintained. Cells can be built as single enclosures, or as two concentric enclosures (Figure 5). Complete containment can be achieved with a single enclosure by maintaining the hydraulic head inside the enclosure below that outside. If the enclosure is being used for experimental purposes or for isolating a subsurface region for remediation, maintaining the interior water level at an elevation dictated by the exterior water level may not be feasible. For example, this could

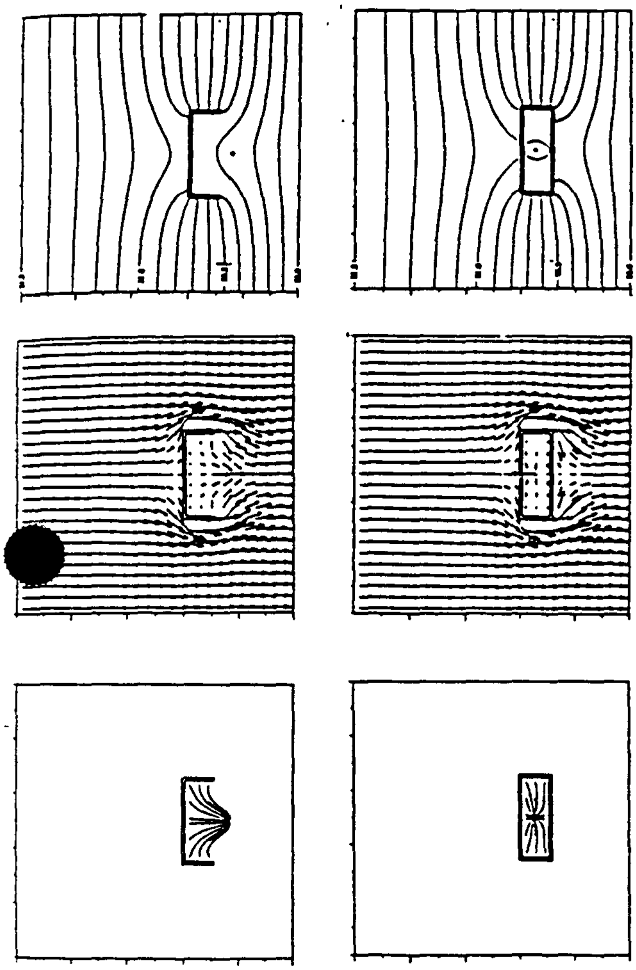


Figure 4: Left: cutoff wall with downstream extensions and extraction well; Right: cutoff well enclosure with interior extraction well.

require that water levels be held below the bottom of the contaminant source zone, in which case many remedial methods would not be effective. Concentric enclosures circumvent this limitation. The hydraulic head in the space between the two enclosures and inside the inner cell can be held at any desired level. As long as the head between the two cells is greater than the head in the inner cell, flow across the inner cutoff wall will be inward, and there will be no outward contaminant flux.

Single and double wall enclosures have been built as facilities for groundwater research and for pilot scale tests of in situ remedial techniques. Similar cells can be used for isolating contaminant source zones, for isolating regions for conducting field trials of in situ remedial measures, and for partitioning an aquifer into segments for remediation. For example, the interior of a cell could be dewatered and volatile contaminants removed by vacuum extraction.

One advantage of the enclosure configuration is that meaningful field tests can be conducted to evaluate the overall hydraulic conductivity of the cutoff wall. Cutoff walls that do not form an enclosure are less amenable to field performance testing. Starr et al. (1992) present results of hydraulic tests of cutoff wall enclosures that have hydraulic conductivities of less than 10^{-8} cm/s.

Cutoff walls that consist of a series of long, narrow cells joined end to end provide the advantage of allowing the entire wall to be subjected to meaningful field performance tests, even if the wall as a whole does not form an enclosure. This configuration also allows a wall to be operated as a hydraulic head barrier, similar to the hydraulic head barrier provided by two concentric cells (Starr et al., 1992).

Cutoff walls can be used for preventing offsite migration of plumes, but must be used in conjunction with extraction wells to prevent the plume from merely deflecting around the ends of the wall. They are better suited for isolating contaminant source zones, particularly the configuration of an enclosure with hydraulic head

A New Type of Steel Sheet Piling with Sealed Joints for Groundwater Pollution Control

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University of Waterloo, Waterloo, ON

SYNOPSIS

A new type of steel sheet piling with joints that can be sealed after driving has been developed. Walls constructed of this sheet piling serve two purposes: to contain zones of contamination so that contaminants will not migrate offsite, and to provide an isolated subsurface environment in which subsurface remediation technologies can be applied with excellent environmental safety. The sheet pile joints incorporate a cavity that can be filled with sealant after driving, and that provides access for quality control operations. Two cutoff wall enclosures have been built in clay near Sarnia, Ontario, to a depth of 7 metres. Fourteen have been installed in a sandy aquifer underlain by silt and clay, near Borden, Ontario, at depths of between 3.5 and 14.7 metres. Field hydraulic tests indicate that hydraulic conductivity values are low enough for environmental control applications. Sealable joint sheet pile cutoff walls overcome many of the practical limitations associated with other cutoff wall types. In addition, sealable joint sheet pile cutoff walls can be constructed with a double cavity version of the joint for additional sealant effectiveness. Both the single and double cavity versions are well-suited to non-conventional configurations that provide a very high degree of containment.

INTRODUCTION

A low hydraulic conductivity cutoff wall is a vertical barrier placed in the subsurface to minimize fluid advection, especially the migration of contaminated or uncontaminated groundwater. Cutoff walls have a long history of use in civil engineering projects, where they are used for reducing groundwater inflow into excavations or beneath dams. Applications for environmental control purposes are more recent, and typically have the goal of preventing contaminated groundwater from crossing site boundaries or discharging into surface waters.

A variety of techniques used for constructing cutoff walls are described by Starr and Cherry (1990). The most common techniques for building walls in soils include slurry trench methods, (soil bentonite, soil attapulgite, and cement bentonite walls), jet grouting, auger cast piles/cassion walls, vibrated beam walls, plastic membrane walls, and steel sheet piling walls.

Conventional sheet piling structures such as retaining walls, cofferdams, or cutoff walls consist of individual sheet piles that are fitted together and driven into the ground. Adjacent sheets are connected by interlocking joints that are designed construction techniques that are amenable to inspection be employed.

Joints between adjacent sheets of conventional sheet piles act as high hydraulic conductivity imperfections, and increase the bulk hydraulic conductivity of a sheet pile cutoff wall. Assuming that a joint can be represented as a 5 mm gap, and that a joint occurs every 50 cm, the value of $A_{imperfection}/A_{total}$ is 10^{-2}. Assuming that the steel portion of the sheet pile has a very low hydraulic conductivity, such as 10^{-13} cm/s, and that the joint hydraulic conductivity is equal to that of the soil inside the joint, which will be assumed to be sand with a hydraulic conductivity of 10^{-3} cm/s, the value of $K_{imperfection}/K_{nominal}$ is 10^{10}. Figure 1 shows that the bulk hydraulic conductivity of the cutoff wall would be 10^{-5} cm/s. However, if the hydraulic conductivity of the joints could be decreased to 10^{-9} cm/s, the value of $K_{imperfection}/K_{nominal}$ would be 10^{4}, and K_{bulk} would decrease to 10^{-11} cm/s.

Various methods of sealing the joints between sheet piles to reduce their hydraulic conductivity have been used. Joints are usually sealed by placing a sealant into each joint before the sheets are coupled and driven into the ground, or by grouting the soil adjacent to each joint after the sheets have been driven. These methods are not well-suited to inspection to confirm that the joints are intact and well-sealed.

WATERLOO SEALABLE JOINT SHEET PILING

Based on the need for sealing sheet piling joints and providing an opportunity for post-driving inspection, researchers at the University of Waterloo developed a new type of steel sheet piling whose joints can be inspected and filled with sealant after the sheets have been driven into the ground. Three versions of Waterloo sealable joint sheet piling have been developed and patents applied for: external sealable cavity, internal sealable cavity, and external + internal sealable cavity.

Sealable joint sheet piling with an external sealable cavity is produced by attaching a steel L section (an 'angle iron') to conventional sheet piling so that a cavity is created adjacent to each joint (Figure 2). Any sheet pile section can be modified using this method. The bottom of each steel L is closed so that little or no soil enters the cavity as the sheets are driven into the ground.

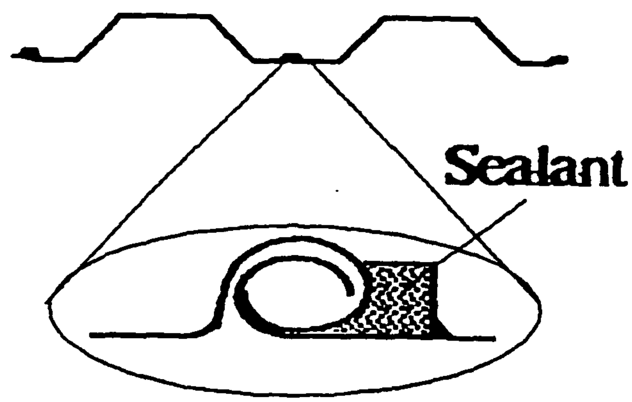

Figure 2: External cavity sealable joint sheet pile.

Sealable joint sheet piling with an internal sealable cavity is produced by forming the sealable cavity as the sheet itself is manufactured (Figure 3). The configuration of the bottom of the cavity largely prevents soil from entering the cavity as the piles are driven.

The third type of sealable joint sheet piling is a combination of the internal sealable cavity with a steel L section attached to form an external cavity at each joint. Two sealable cavities at each joint provide more security that the joints are well sealed, and also provide an opportunity for using more than one sealant at each joint (Figure 4).

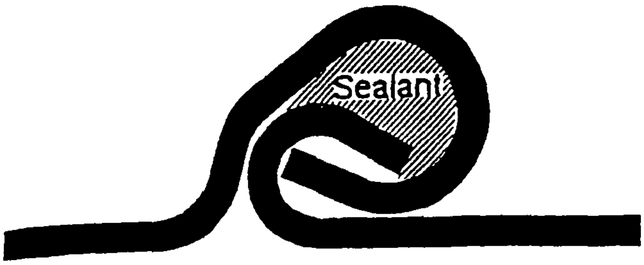

Figure 3: Internal cavity sealable joint sheet pile

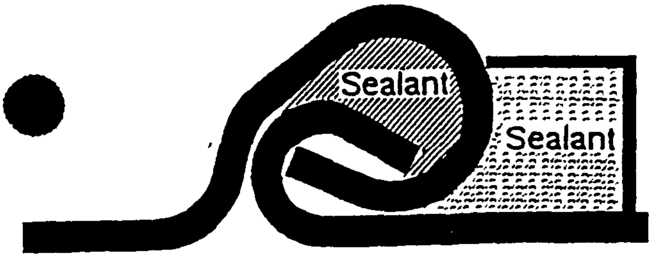

Figure 4: Dual cavity sealable joint sheet piling.

In all three joint configurations, a plate at the bottom of the joint displaces soil laterally as the sheets are driven and the joints remain largely soil-free. The soil that does enter the joints is relatively loose and easily removed by jetting with water.

CONSTRUCTION AND SEALING TECHNIQUES

Cutoff walls made from sealable joint sheet piling are built using standard techniques for sheet pile wall construction. After driving, any foreign matter is removed from the joints by washing with a stream of water. Particularly in sandy materials, soil enters the sealable cavities through gaps at the bottom and sides of the cavities as the sheets are driven into the ground. After the joints have been cleaned, a grouting hose is lowered to the bottom of the joint, sealant is injected, and the hose is withdrawn as the cavity is filled with grout.

The joint can be inspected between cleaning and sealing. Lowering the washing and grouting hoses to the bottom of the cavity confirms that the cavity is open and hence that sealant can be placed into the complete length of the joint. A joint inspection tool is being developed that will log the size of the cavity and sense the presence of the adjacent sheet, which will confirm that the sheets have not pulled apart during driving. If it is discovered that a joint has failed and cannot be filled with sealant, then it can be sealed by grouting the soil adjacent to the joint.

A variety of joint sealant materials can be used, depending on project requirements. Two types of sealants have been used in field trials to date: bentonite-based grouts, and an organic polymer that absorbs water and swells. On going research is evaluating additional sealant materials.

HYDRAULIC TESTS

A total of sixteen cells has been built for research purposes. The cells range in size from 2 m x 2 m to 10 m x 10 m, and from 3.5 m to 14.7 m in depth. The cells have been built in a surficial sandy aquifer underlain by a silt and clay aquitard at Canadian Forces Base Borden, Ontario, and in a weathered and fractured clay unit overlying unweathered clay near Sarnia, Ontario. In most cases, the cells extend into a low hydraulic conductivity material at depth. Cells that have a continuous low hydraulic conductivity bottom can be subjected to hydraulic tests that indicate the bulk hydraulic conductivity of the sealable joint sheet pile walls that form the sides of the cell.

The bulk hydraulic conductivity is measured by displacing the water table inside of the test cell from the water level outside and monitoring the recovery rate. Field test data are compared with model simulations for various values of K_{bulk} for the wall. The assumptions incorporated in the model include that the wall has uniform hydraulic conductivity, flow through the wall is at steady state, and all water leaving or entering the cell flows through the walls, with no water flowing through the low hydraulic conductivity material at the bottom of the cell. If any water flows out of the cell through the bottom, the calculated value of K_{bulk} will be greater than the actual value, so the values for K_{bulk} determined from the hydraulic tests are an upper bound on the true value. The corrugated sheet pile is simulated as a non-corrugated panel located along the centreline of the sheet piles, with a thickness equal to that of the sheet pile. To avoid errors introduced by uncertainties in the value of specific yield, which varies substantially when the water table is close to ground surface, the test is conducted with the water level in the cell above ground surface, in which case specific yield is equal to 1.

Simulations and field data are reported in terms of relative head difference, which is the difference in hydraulic head across the test cell wall at any time, normalized by the difference in head at the start of the test.

The hydraulic test of the first sealable joint sheet pile test cell constructed of cold-rolled sheet piling with an external sealable cavity indicated a bulk hydraulic conductivity of 10^{-4} cm/s before the joints were sealed, and 10^{-7} cm/s after the joints were sealed with a bentonite grout. This clearly demonstrates that sealing the joints between sheet piles substantially reduces the bulk hydraulic conductivity of sheet pile cutoff walls. Better sealants have been developed and sheet piling with an internal sealable cavity has been produced since the first hydraulic test. Figure 5 shows a test cell constructed of internal cavity sealable joint sheet piling. The hydraulic test was conducted on the inner 1.5 m x 2.6 m cell. The outer 3.5 m x 4.0 m cell was constructed to keep the water table on the exterior of the inner cell at a constant elevation, to conform with the mathematical model. The test cell extends 12.2 m through a surficial aquifer and into an underlying clay aquitard to a total depth of 14.7 m, and the joints were sealed with bentonite.

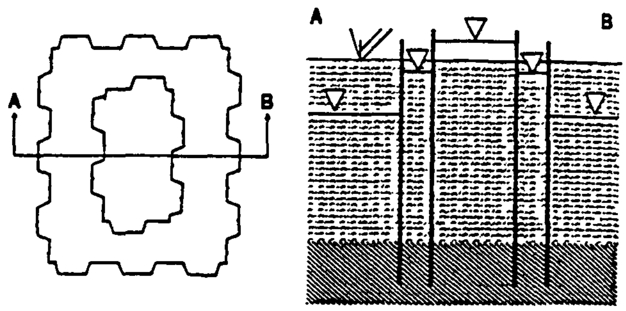

Figure 5: Internal cavity sheet pile test cell.

Figure 6 shows the results of the hydraulic test. The bulk hydraulic conductivity of this cutoff wall is 6×10^{-9} cm/s. Additional tests will be performed after the bentonite grout in the joints has been replaced with another sealant. We are confident that a lower bulk hydraulic conductivity can be achieved by using better sealants. Preliminary tests using an organic polymer sealant in a different test cell constructed in the same sandy aquifer indicate a bulk hydraulic conductivity of 4×10^{-10} cm/s.

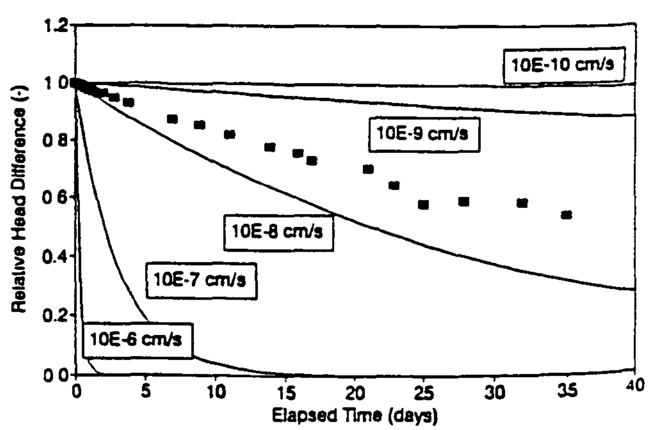

Figure 6: Hydraulic test data from internal cavity sealable joint sheet pile test cell sealed with bentonite.

The same organic polymer was used in a test cell with external sealable cavities, which was built in weathered clay near Sarnia, Ontario. The sealant, Dow-Schlumberger Chemical Seal Ring, was placed into the cavities as a liquid that sets to form a rubbery material and swells as it absorbs water. Figure 7 shows hydraulic test results. The bulk hydraulic conductivity of the cutoff walls is between 10^{-9} and 10^{-10} cm/s, similar to the value observed in the preliminary test described above.

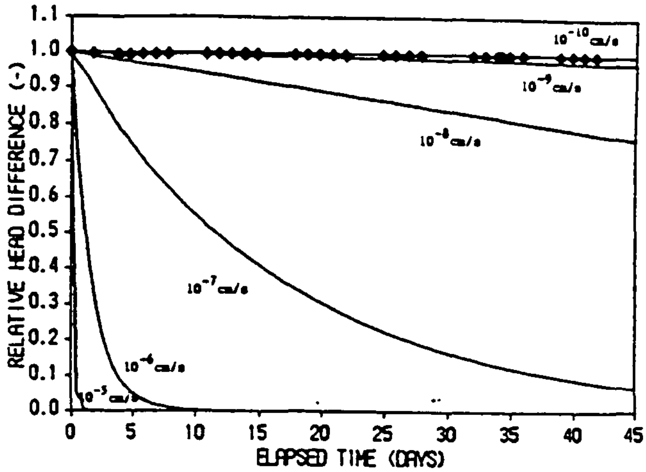

Figure 7: Hydraulic test data from external cavity sealable joint sheet pile test cell sealed with organic polymer.

COMPARISON TO REGULATORY CRITERIA

Given that the purpose of constructing a cutoff wall is to reduce the flux of water, and hence the flux of contaminants, cutoff walls of different types should be compared on the basis of the flux of water passing through them. The flux through a wall is described by the Darcy equation:

$$q = -K_{bulk}\frac{\Delta H}{b} \tag{2}$$

$$= -\frac{K_{bulk}}{b}\Delta H \tag{3}$$

where:

q	=	flux	$[LT^{-1}]$
K_{bulk}	=	bulk hydraulic conductivity of wall	$[LT^{-1}]$
ΔH	=	difference in hydraulic head across the cutoff wall	[L]
b	=	cutoff wall thickness	[L]

For a given head difference across a cutoff wall, the flux is proportional to the ratio of bulk hydraulic conductivity to thickness. Hence, walls should be compared on the basis of this ratio, not on hydraulic conductivity alone.

There are few regulatory criteria for cutoff walls. However, the State of California specifies that soil bentonite cutoff walls be at least 24 inches (0.61 m) thick, and have a hydraulic conductivity of 10^{-6} or 10^{-7} cm/s or less, depending on the application (California Code of Regulations, 1990). Cutoff walls that meet the California criteria and other types of cutoff walls are compared in Table 1.

The Waterloo sheet pile cutoff wall sealed with the organic polymer has better performance than that required by California for clay cutoff walls. However, the wall sealed with bentonite grout does not meet California requirements. The flux through the bentonite sealed wall exceeds the less stringent California criteria by a factor of five. It should be pointed out that this cell was sealed during cold weather in mid-winter. It is likely that a better performance can be achieved if the joints are sealed under less difficult conditions.

The bulk hydraulic conductivity of the cutoff wall can be decreased by using a less permeable sealant, and we are confident that sufficiently impermeable sealant can be employed. Lab and field trials with an improved bentonite grout and other sealants are scheduled for summer, 1992.

Table 1: Cutoff wall performance criteria and observed performance.

Wall Type	K_{bulk} (cm/s)	K_{bulk} (m/s)	b (m)	K_{bulk}/b (1/s)
Soil Bentonite California #1	10^{-6}	10^{-8}	0.61	1.6×10^{-8}
Soil Bentonite California #2	10^{-7}	10^{-9}	0.61	1.6×10^{-9}
Internal Cavity Sheet Pile Sealed with Bentonite	6×10^{-9}	6×10^{-11}	0.0075	8.0×10^{-8}
External Cavity Sheet Pile Sealed with Organic Polymer	10^{-9}	10^{-11}	0.010	1.0×10^{-9}

ADVANTAGES AND DISADVANTAGES

One of the major advantages of Waterloo sealable joint sheet piling over other construction methods is that excavation of subsurface materials is not required. This makes it a relatively clean technique, and minimizes the costs associated with health and safety precautions and disposal if contaminated soils are excavated during construction. In particular, shipping costs and tipping fees for disposing of contaminated spoil or cuttings can be a major expense, particularly on large projects. Use of sealable joint sheet piling avoids this expense since there is no excavation of contaminated soil.

The volume of the joints that must be sealed is relatively small, so it is feasible to use sealants that have superior performance, but are too expensive to use in large quantity. If sealants like bentonite that are easy to remove from the joints are employed, then the joints can be cleaned and resealed if sealant integrity or durability is doubtful. Secondly, use of a removable sealant allows the sheets to be removed from the ground and used elsewhere, which could be advantageous for temporary installations for construction, for isolating portions of a site for pilot scale tests, or for remediation of a site in sections.

Little construction equipment or ancillary facilities are required, and installation is rapid. This makes sealable joint sheet pile cutoff walls well suited for small projects, where mobilization and setup charges make other techniques more expensive. Damage to the landscape and above ground facilities is minor, compared to other techniques. Through the use of corner sections, irregular geometries can be easily constructed. In contrast, it is inconvenient to construct corners using slurry trench methods. These features make sealable joint sheet piling well suited for use on small projects, sites with limited access, and in projects where construction time is limited.

Equipment that installs piles by pressing them into the ground using hydraulics, instead of the conventional hammering or vibrating methods, is now available in North America. Use of this equipment allows cutoff wall construction in urban areas without the noise and vibration usually associated with pile driving. Unlike slurry trench methods, topography and depth to water have little effect on this method. Sheet pile cutoff walls can be installed through surface water bodies by working off barges or all terrain vehicles, without having to construct embankments in low-lying areas.

Construction inspection techniques for sealable joint sheet pile cutoff walls are straightforward. First, penetration of the wall into an impermeable unit at depth must be confirmed, which can be accomplished by comparing the depth to which the piles are driven with the required depth determined during preconstruction site investigation, and by observing the resistance to driving during construction. Second, the joints can be inspected to confirm that the sheets have not separated, and that they are open to the full depth of the wall. A geophysical tool that improves this portion of the inspection procedure is being developed. Third, the joint sealing operation can be monitored using conventional quality control procedures for grouting operations.

The disadvantages of sealable joint sheet piling are that it is not suitable for sites where the wall must penetrate boulders, where soils are very stiff, or where the cutoff wall must be keyed into bedrock. If hydraulic pile installation equipment is not available, excessive settlement of structures due to vibration of loose granular soils could preclude use of sheet piling. Finally, the cost of materials is higher for sheet pile walls than for other types of walls. However, costs are project specific, and if costs for all aspects of the project are considered, particularly disposal of contaminated soil, then the higher cost of materials for sheet piling may be offset by savings in other parts of the project.

APPLICATIONS

Sealable joint sheet pile cutoff walls can be used for constructing conventional, straight cutoff walls. Enclosures like the ones used in the field hydraulic test program are easily built. These enclosures can be used to isolate highly contaminated subsurface regions, which can then be subjected to remedial measures that would not be feasible without hydraulic isolation. Enclosures are also useful for conducting pilot scale field trials of remedial measures (Fountain et al., 1990). Narrow rectangular enclosures can be constructed, dewatered, excavated and shored, and then backfilled with a specialty granular material that promotes degradation of organic solutes (Gillham et al, 1992) or other reactions to accomplish passive in situ plume remediation.

Sealable joint sheet piling has been used for constructing cutoff walls that provide a hydraulic head barrier, in addition to a low hydraulic conductivity barrier. With a conventional cutoff wall, there is a flux of water through the wall from the side where the hydraulic head is higher to the side where it is lower. Advection of contaminated water through the wall can be prevented by maintaining the hydraulic head on the contaminated side of the wall below that on the clean side of the wall, so that advection is from the clean side to the contaminated side.

Figure 8 shows a rectangular enclosure that surrounds a highly contaminated portion of the subsurface. Advection of contaminated groundwater outward through the walls can be prevented by depressing the water level inside the enclosure using extraction wells. In pilot scale remediation experiments or a full scale remediation program inside the enclosure, maintaining the water level inside the cell below the naturally fluctuating level outside is at best a nuisance, and may limit the effectiveness of the remedial activities if water levels inside the cell must be below the top of the zone that requires remediation.

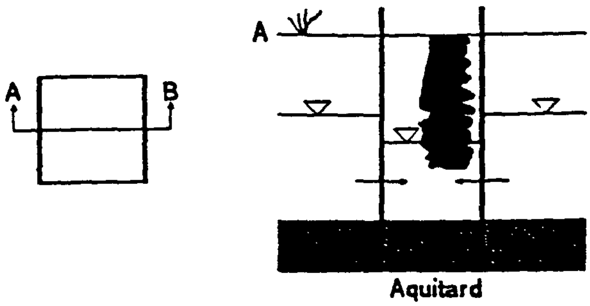

Figure 8: Single wall enclosure.

Figure 8 shows two concentric cells. The water level in the space between the inner and outer cells is maintained above the level in the inner cell by a simple float valve system. This allows the water level inside the inner cell to be maintained at any desired elevation, regardless of fluctuations in the external water level. Water will flow into the inner cell from the space between the cells, so water must be periodically extracted from the inner cell. Three pairs of concentric cells of this type have been built and used for isolating portions of the subsurface in which liquid phase tetrachloroethylene was released into a granular aquifer for experimental purposes (Kueper et al., 1992; Brewster et al., 1992; Schnarr, 1992).

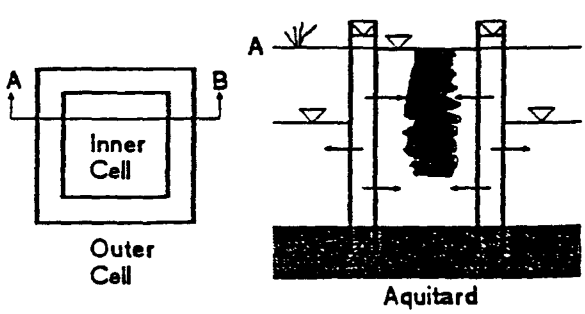

Figure 9: Concentric test cells with hydraulic barrier in the space between the inner and outer cell walls.

A similar approach can be used in walls that do not form enclosures. Instead of constructing a single wall, two parallel walls are built, and the space between the two walls is partitioned into watertight compartments or cells by transverse walls. The water level in each compartment is maintained higher than the water level on the contaminated side of the wall adjacent to that cell, so advection of contaminated water through the wall does not occur.

This configuration allows rigorous field testing of the cutoff wall by conducting a hydraulic test of each compartment, similar to the hydraulic test described previously. Thus, the hydraulic integrity of the wall, including the connection with an underlying aquitard, can be documented by post construction field tests. A cell with an anomalously high bulk hydraulic conductivity would be suspected of having a leaking joint or inadequate key into the aquitard. Investigations for locating and repairing the imperfection would focus on the high hydraulic conductivity cell, instead of subjecting the entire wall to remedial investigation and repair.

CONCLUSIONS

A new type of steel sheet piling with joints that can be inspected and sealed after driving has been developed. Field tests demonstrate that sealing the joints decreases the bulk hydraulic conductivity of a sheet pile cutoff wall to levels that are acceptable for environmental control applications.

Sheet pile cutoff walls can be practically constructed in settings where other types of cutoff walls would be difficult to construct. Test cells for research purposes have been constructed using sealable joint sheet piling. Field tests indicate bulk hydraulic conductivity values of 10^{-7}-10^{-10} cm/s. Similar enclosures could be used at commercial sites for contaminant source isolation and remediation. Single and double walls can be built; double walls provide a hydraulic head barrier to flow, in addition to a low hydraulic conductivity barrier.

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ATTACHMENT 6

Remedial Action Plan
Site 103, NAS Key West, Florida
Response to Comments

CONTAMINANT TRANSPORT CALCULATION
NAS Key West, Building 103, Truman Annex

The calculation of contaminant transport in groundwater is based on the characteristics of the contaminant in question and the hydraulic properties and the fraction of organic carbon of the media through which the contaminant and the groundwater are traveling. The ratio of the amount of contaminant sorbed to the soil to the contaminant dissolved in water is calculated as follows.

$$f_{oc} \times K_{oc} = K_d$$

Where

f_{oc}	=	fraction of organic carbon in the soil (%)
K_{oc}	=	soil adsorption coefficient for the contaminant considered (dimensionless)
K_d	=	soil/water partitioning coefficient or sorbed to dissolved ratio (dimensionless)

The retardation factor relates the tendency of the aquifer media to reduce the migration rate of the contaminant relative to that of the groundwater. The retardation factor is determined using the equation below.

$$R_d = 1 + \left(\frac{\rho_s}{v}\right) \times K_d$$

Where

R_d	=	retardation factor (dimensionless)
ρ_s	=	bulk density of soil (gm/cc)
v (nu)	=	soil porosity (%)
K_d	=	soil/water partition coefficient or sorbed to dissolved ratio (dimensionless)

If the pore water velocity is known, the contaminant transport velocity can be determined based on the relation:

$$V_c = \frac{V_w}{R_d}$$

Where

V_c	=	contaminant transport velocity (ft/year)
V_w	=	pore water velocity (ft/year)
R_d	=	retardation factor (dimensionless)

Knowing the length of the path a contaminated water particle travels, the time for contaminant transport can be determined using the following equation.

$$T_b = \frac{L}{V_c}$$

Where

T_b	=	time for contaminant to traverse the given flow path L (years)
L	=	length of the flow path (feet)
V_c	=	contaminant transport velocity (ft/year)

Finally, if the half life of the contaminant and the initial contaminant concentration are known, the final concentration of the contaminant after it travels the length of the flow path can be calculated using the following equation.

$$C_f = C_i \times (0.5)^{\frac{T_b}{t_{1/2}}}$$

Where

$t_{1/2}$	=	greater half life of the contaminant in either groundwater or in an anaerobic state, (years)
C_i	=	initial contaminant concentration (ppb)
C_f	=	concentration of contaminant at time T_b (ppb)

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CONTAMINANT TRANSPORT CALCULATION
NAS Key West, Building 103, Truman Annex

PROJECT: NAS Key West, Building 103, Truman Annex			CHECKED BY:
DATE: 9 DECEMBER 1994			ENGINEER: FJU

Variable	Value	Units	Description
foc	0.70	%	Fraction of organic carbon in soils
Koc	549.00	dimensionless	Soil Adsorption Coefficient for Naphthalene
Kd	3.84	dimensionless	Soil/Water Partitioning Coefficient
p	2.72	gm/cc	Bulk Soil Density
nu	0.25	dimensionless	Soil Porosity
R	42.81	dimensionless	Retardation Factor
deltH	2.00	feet	Difference in Water Table elevation between ground and surface water
L	94.00	feet	Length of Water Particle Flow Path
I	0.02	dimensionless	Hydraulic Gradient
K	10.00	ft/day	Hydraulic Conductivity
Vw	0.85	ft/day	Pore Water Velocity
	310.64	ft/year	Conversion
Vc	7.26	ft/year	Contaminant Transport Velocity
Tb	12.95	years	Time for contaminant to reach surface water
t1/2	0.71	years	Half life of Naphthalene in groundwater
Ci	408.00	ppb	Initial Concentration of Naphthalene
n	18.33	dimensionless	Number of half lives during time Tb
Cf	0.001	ppb	Concentration of Naphthalene at time Tb